REPORT
OF THE MISSISSIPPI VALLEY COMMITTEE
OF THE
PUBLIC WORKS ADMINISTRATION

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OCTOBER 1, 1934

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REPORT

OF THE MISSISSIPPI VALLEY COMMITTEE

OF THE

PUBLIC WORKS ADMINISTRATION

Submitted October 1, 1934

To

HAROLD L. ICKES, Administrator
Federal Emergency Administration of Public Works

UNITED STATES GOVERNMENT PRINTING OFFICE WASHINGTON : 1934

LETTER OF TRANSMITTAL

Federal Emergency Administration of Public Works,
Washington, D. C. October 1, 1934.

Hon. Harold L. Ickes, *Administrator,*
Federal Emergency Administration of Public Works,
Washington, D. C.

My Dear Mr. Administrator:

The Mississippi Valley Committee submits herewith its report on principles, policies, conditions, and problems of the use and control of water in the Mississippi Drainage Area. The Committee has endeavored to bring into common focus many phases of the subject which usually have not been treated in their relations to each other.

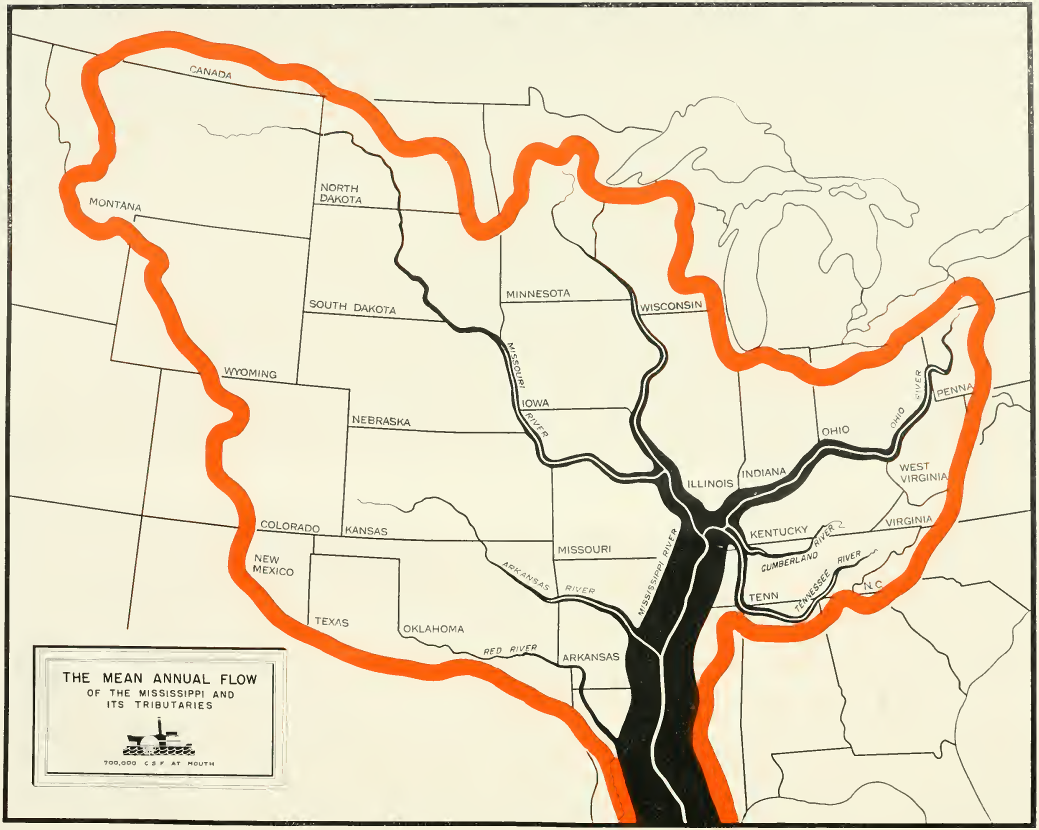
The Committee wishes to express its cordial appreciation of the consideration and helpfulness which it has been accorded by Federal Emergency Administration of Public Works.

Very respectfully yours,

The Mississippi Valley Committee.
By Morris L. Cooke, *Chairman.*

*Planning for the use and control of water is planning for most of the basic functions of the life of the Nation. We cannot plan for water unless we also consider the relevant problems of the land. We cannot plan for water and land unless we plan for the whole people. It is of little use to control rivers unless we also master the conditions which make for the security and freedom of human life. * * * The need for planning arises out of the needs and desires of the people. Under the proven system of democracy no plan can be imposed upon the people. Government may inform, educate, and guide. It may mobilize resources for the common task. It cannot dictate. What must be sought is effective means for carrying out the common purpose, not only in the interest of the living generation but for the protection and enhancement of the lives of all the generations to come. * * * We are but tenants and transients on the earth. Let us hand down our heritage not only unimpaired but enriched to those who come after us.*

MISSISSIPPI VALLEY COMMITTEE.



THE MEAN ANNUAL FLOW
OF THE MISSISSIPPI AND
ITS TRIBUTARIES

700,000 C S F AT MOUTH

THE MISSISSIPPI VALLEY COMMITTEE REPORT

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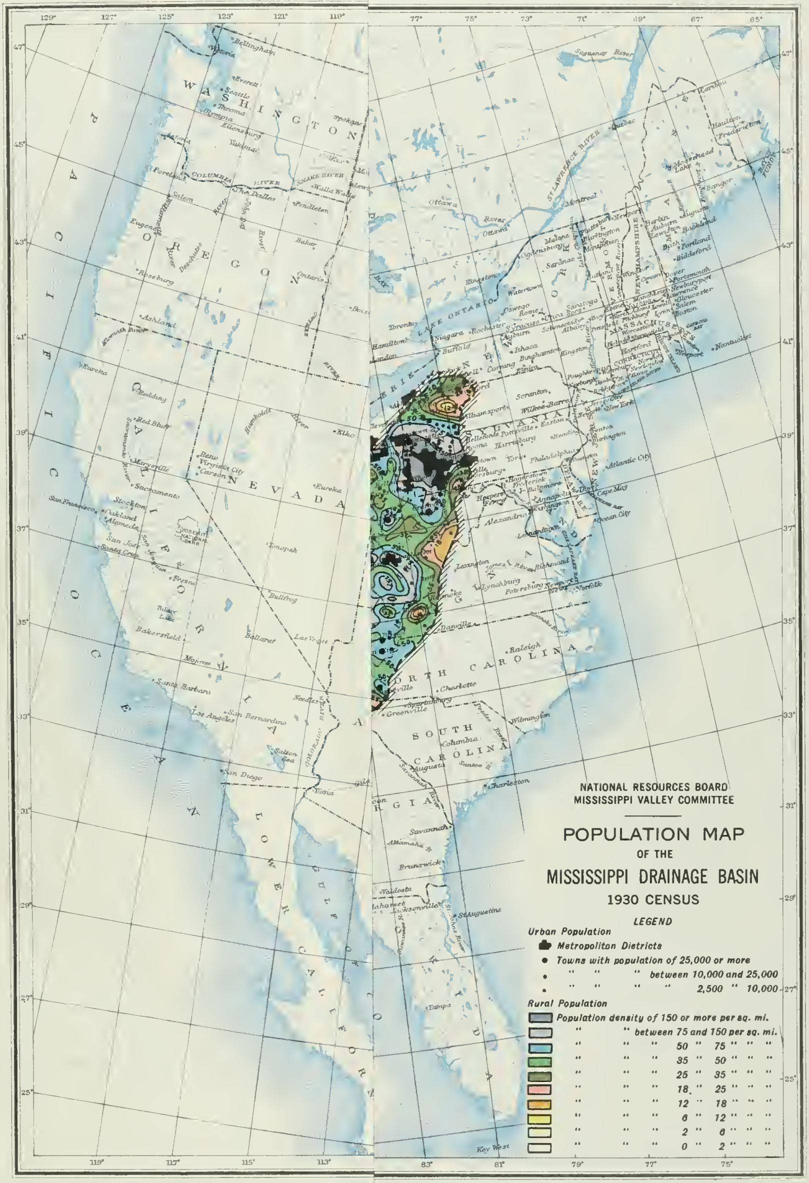
BOOK I PROBLEM

SECTION I

SUMMARY

2 Above, source of run-off in the Rocky Mountains. Below, destination of run-off in Cypress Swamps of the South.



NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE

POPULATION MAP
OF THE
MISSISSIPPI DRAINAGE BASIN
1930 CENSUS

LEGEND

Urban Population

- ■ *Metropolitan Districts*
- ● *Towns with population of 25,000 or more*
- • *" " " between 10,000 and 25,000*
- · *" " " " 2,500 " 10,000*

Rural Population

- ▨ *Population density of 150 or more per sq. mi.*
- ▨ *" " between 75 and 150 per sq. mi.*
- ▨ *" " " 50 " 75 " " "*
- 🟩 *" " " 35 " 50 " " "*
- ▨ *" " " 25 " 35 " " "*
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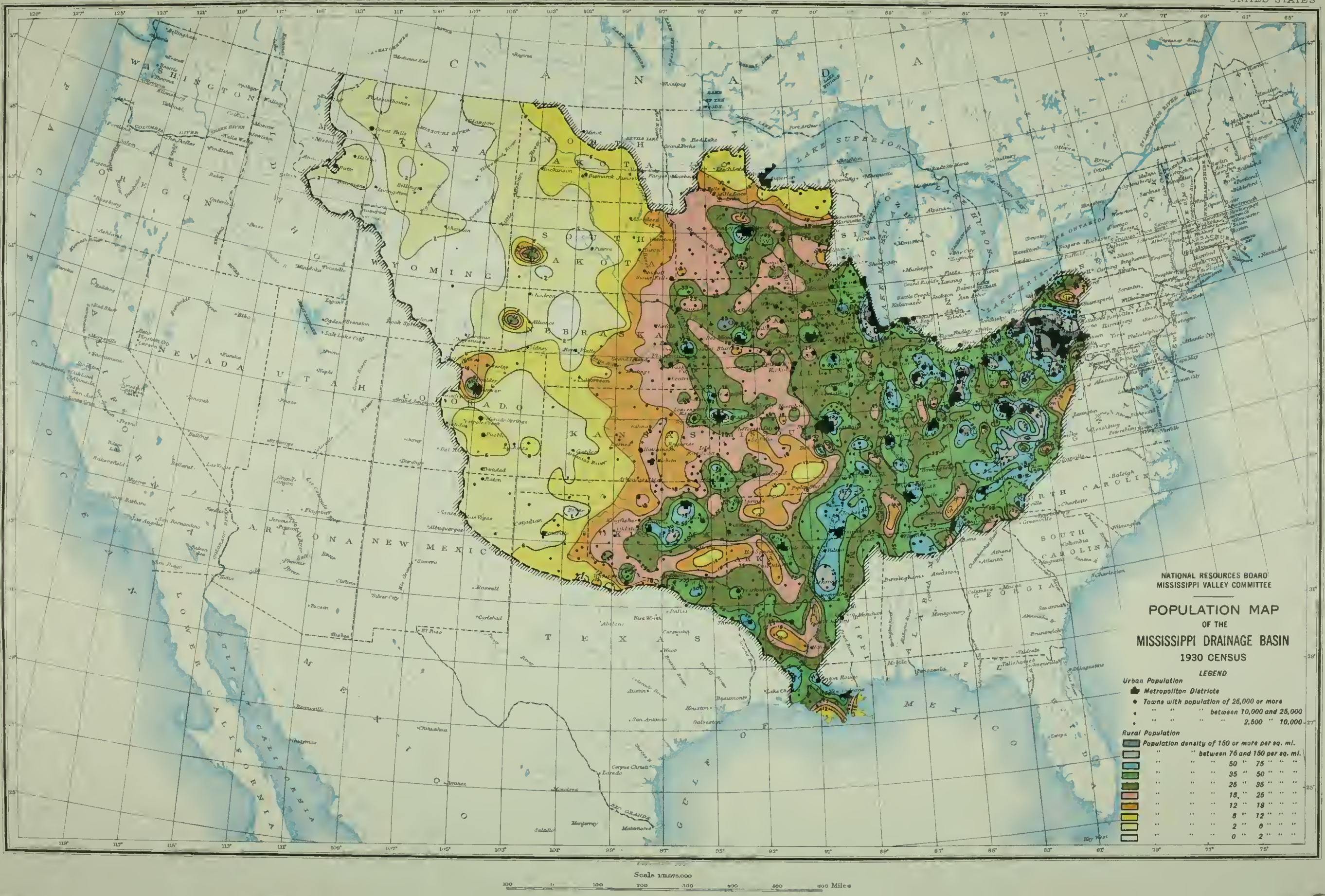

NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE

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I. Land, Water, and People

> "*Make no little plans. They have no magic to stir men's souls.*"—*Charles D. Norton.*

The time has passed when isolated or unrelated plans were adequate to American needs. When one strand in the interwoven web of our national fabric is touched every other strand vibrates. Land, water, and people go together. The people cannot reach the highest standard of well-being unless there is the wisest use of the land and water.

The divisions into which the Mississippi Valley Committee was forced, by the sheer logic of the situation, to analyze its problem will indicate the amazing diversity of the task of using and controlling water. Flood control, low-water control, navigation, power, water supply, sanitation, and erosion are integral parts of the picture. All of these elements are met with in the Great Valley. All of them may be encountered in the treatment of a single stream.

Merely to list them is to suggest that we cannot plan—that we can hardly hope to develop even a single sound project—unless we study also the uses of the land. So we have other factors we cannot overlook; agriculture and irrigation, industry and commerce, water storage, forestry, recreation, the conservation of wildlife.

Every plan and detail of a plan must be checked against as many of these factors as are pertinent to the particular case if we are to be certain of wholly beneficial results. From a consideration of projects we come to the consideration of a pattern on which are dependent the lives and happiness of millions now living and millions still to be born.

Engineering does not exist for its own sake. It is of little use to control rivers if we cannot thereby improve the quality of human living. Therefore, the final and most significant element which the committee has considered is neither land nor water, but the people who live on the land and are dependent on the water.

II. Water in Motion

A drainage basin, big or little, is a region through which water moves. No act of man can permanently halt this flow of power, nor even diminish it to an appreciable degree. The water must come down—we could not stop it if we would. We can, however, figuratively as well as literally, canalize it so that it will do what we want it to do and not do what we do not want it to do.

The Problem of Control: The ideal river, which would have a uniform flow, does not exist in nature. Something usually has to be done, to equalize the flow or to take advantage of variations in flow, if the stream is to resemble even remotely an ideal river. But before this stage can be reached the question has to be answered, For what or for whom is the river to be ideal? The problem of control involves not only the physical nature of the stream, but the often conflicting claims of various uses and various users. Scientific planning requires a use pattern for each community, district, or region, as well as a geographical pattern which will reflect as fairly as possible the dominant needs of each locality.

The same principle must hold when we attempt to prevent a stream or a river system from doing damage. There is no one method of flood control which is applicable to the entire Mississippi system. The improvement of natural channels; the building of reservoirs—sometimes well adapted for purposes of irrigation and power; the construction of levees, such as now exist along the lower Mississippi; reforestation and a change in certain areas from tilled crops to grass crops, may all play a part in slowing down the rush of water to the sea, or in keeping it away from cities, towns, and valuable lands.

Floods pay no attention to political jurisdictions. Any coordinated system of control will demand the cooperation of neighboring States with each other as well as the cooperation of States with the Federal Government. Obviously the Federal Government should bear its share of the costs and the responsibility. Obviously, too, the States should do the same. To make this easily possible we need uniform State flood control laws, Federal legislation to expedite interstate compacts, and a permanent policy of Federal participation based on accurate estimates of the benefits to be derived. The integrity of State and local governments is certain to be impaired if the Federal Government is regarded as a kind of Santa Claus.

It is suggested that the Federal Government might pay 30 percent of the cost of labor and materials for projects of chief benefit only to local communities; a larger proportion as the measurable general benefits increased; and 100 percent of the construction cost when the benefits to be derived were, as they are now recognized to be on the lower Mississippi and its backwater areas, a national affair. In each instance there should be responsible and legally constituted local agencies with which the Government could deal.

The same principles that are applied to flood control may be applied to low-water control. Sometimes the multiple purposes of power development, irrigation, navigation, water supply, low-water control, and even flood control may be served by a single project. As in the case of flood control, low-water control may be paid for by the different agencies in proportion to the benefits received. Since pollution, by sewage or industrial waste, is a common accompaniment of low-stream stages in closely settled regions it is reasonable to ask that local authorities and industrial interests shall control this element as a preliminary to Federal participation.

The Federal Government manifestly should not be asked to police local streams.

Navigation: Inland waterways in the United States fixed the lines which the first westward migrations were to follow. As highways, canals and finally railroads were thrust westward from the Atlantic coast, waterways lost their supreme significance. Nevertheless they have continued to play a part in the national life, billions of dollars have been invested in them, and they have a romantic and traditional interest which cannot be disregarded.

Certain disadvantages attach to any river development: Rivers are crooked and often do not follow normal lines of traffic movement; reshipment is often necessary; variations in the water level make it difficult to establish proper docking and warehousing facilities; the northern waterways are closed by ice during many months of the year.

On the other hand some waterways have continued to prove economically justifiable; inland waterway transportation has sometimes had a chastening influence on railroad rates; and there is already a large Federal, State and local investment in waterways which would be lost if they were abandoned. Furthermore, navigation may well be part of a plan which provides also for irrigation, flood control, low-water control and power development. We must measure its costs and advantages in their relation to some or all of these other elements.

Down to the end of 1932 the United States Government had spent a little less than two billion dollars on river and harbor improvements, of which 94 percent was expended after 1882, 74 percent after 1906, and 46 percent after 1920. Of this amount about a billion and a half dollars were chargeable to navigation alone, and about $440,000,000 to navigation on the Mississippi river system. We have 27,406 miles of inland waterways which are legally defined as navigable, of which 12,798 miles nearly half—are in the Mississippi system.

These legally navigable channels are in some cases no more than that. We need new estimating, accounting and cost-finding technique not only to weigh the advantages and disadvantages of river transportation, but to determine the proper place of inland waterways in a coordinated national transportation system. It may be desirable to introduce a new element by imposing charges where they are justified by special services and special facilities and where the traffic can bear them.

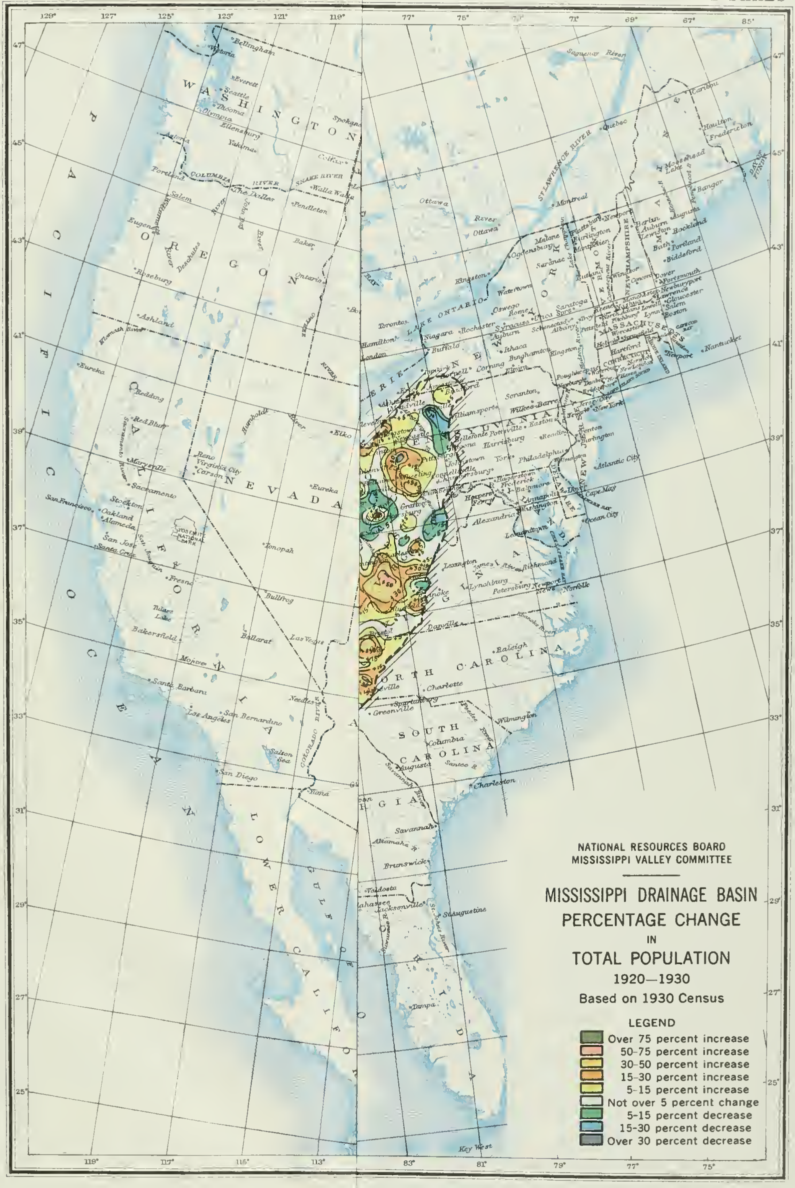
The movement toward ultimate unification might be hastened by the setting up of a commission to regulate water rates and to cooperate with the Interstate Commerce Commission in fixing joint rail and water rates. In time, with experience and with the accumulation of data which we now lack, the two agencies might be combined.

Power: The production and distribution of electricity, more than most other factors, demands Valley-wide coordination as part of a unified national system. The opportunities for power development are great, out of a potential of 16,000,000 kilowatts on the Mississippi and its tributaries only 2,000,000 have so far been utilized. In cases where potential power is not near an existing market a region-wide tie-up—an electrical "pool" to which all power sources would contribute—would often make it economically feasible to develop. In any such combination there would be a residue of continuous power, even when many individual plants were contributing only a part of the time.

If coordination is taken as the key we see the unfortunate effects of the present set-up in a power map which shows a "crazy patchwork of operating areas" and "a mass of independent unrelated generating units". Congested areas have more installed power than their inhabitants can utilize under present conditions; other areas, especially the rural ones, have little or no electric service, and there is a general underconsumption of power.

Coordination, under Government leadership, would not only benefit the consumer, but would aid the private producers by eliminating unnecessary duplications of plant

UNITED STATES



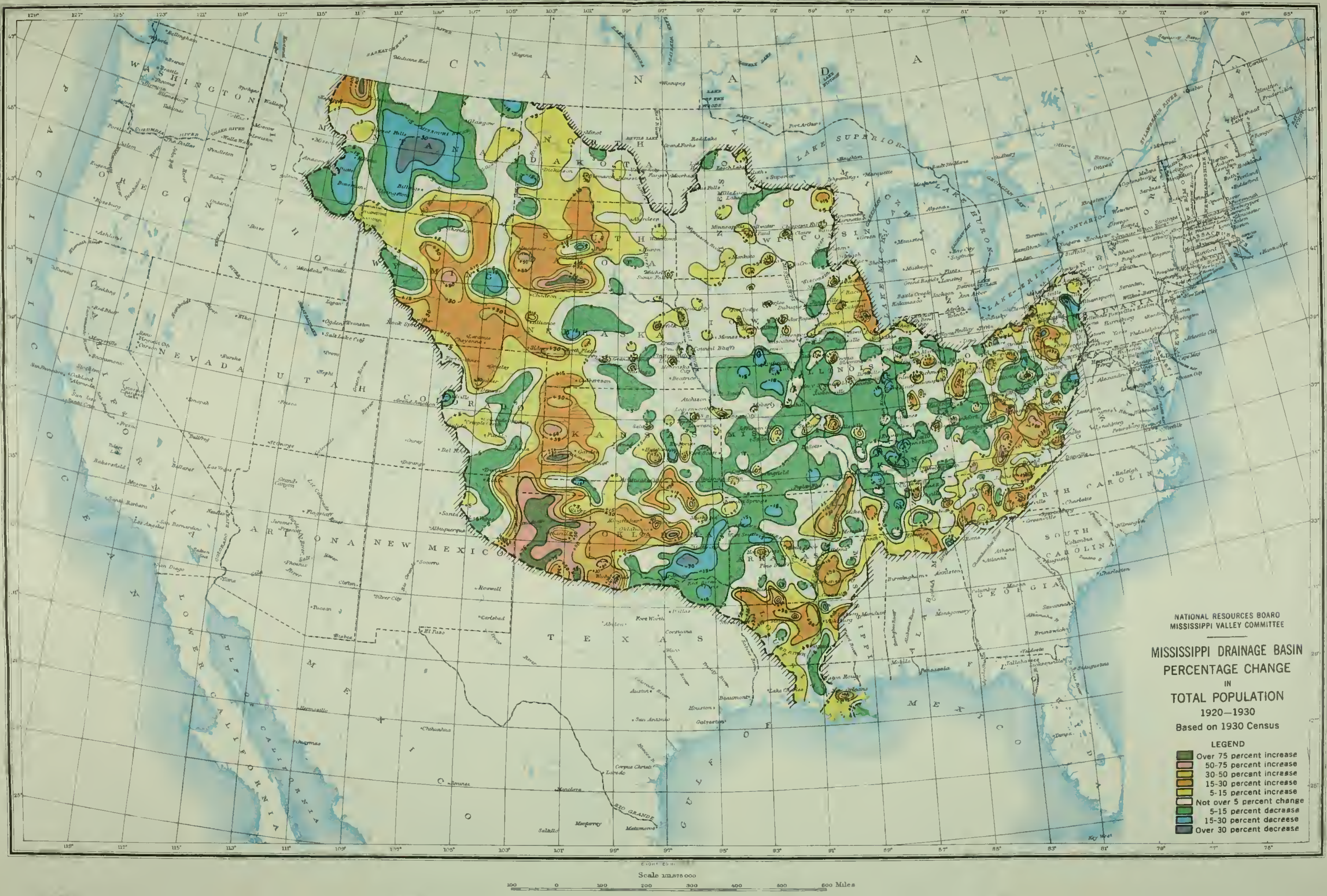
NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE

MISSISSIPPI DRAINAGE BASIN
PERCENTAGE CHANGE
IN
TOTAL POPULATION
1920—1930

Based on 1930 Census

LEGEND

- 🟩 Over 75 percent increase
- 🟥 50-75 percent increase
- 🟨 30-50 percent increase
- 🟧 15-30 percent increase
- 🟨 5-15 percent increase
- ⬜ Not over 5 percent change
- 🟩 5-15 percent decrease
- 🟦 15-30 percent decrease
- ⬛ Over 30 percent decrease



NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE

MISSISSIPPI DRAINAGE BASIN PERCENTAGE CHANGE IN TOTAL POPULATION

1920—1930

Based on 1930 Census

LEGEND

■	Over 75 percent increase
■	50-75 percent increase
■	30-50 percent increase
■	15-30 percent increase
■	5-15 percent increase
□	Not over 5 percent change
■	5-15 percent decrease
■	15-30 percent decrease
■	Over 30 percent decrease

and equipment, stabilizing service and making available new sources of energy.

The Federal Government should regulate transmission, regardless of the number of generating plants or transmission lines it may ultimately own. During the next 20 years it could profitably spend a billion dollars on river works in the Mississippi Valley, half of which would be for self-liquidating power installations. With this nucleus it could experiment as well as regulate.

Beyond lies the great task of rural electrification—the need for which is indicated by the fact that only one farm out of every seven in the United States is now electrified, even counting private power installations. Only 1 in 10 of the nation's farms, only 1 in 16 of those in the Mississippi Valley, actually buys electricity from power lines.

An allotment of $100,000,000 to build independent, self-liquidating rural electric projects would be a safe and socially justifiable experiment. Such an enterprise would not compete with private capital, since it would serve territory not now served or likely to be served in any other way. There is every reason to expect that the low rates which would be possible would result in a great expansion in the rural uses of electricity and a consequent increase in rural living standards.

Water Supply and Sanitation: The provision of an ample supply of pure water for domestic uses is a problem throughout the basin. Low water everywhere intensifies pollution. Planning obviously must look far ahead, providing for future supplies and for purification works; establishing water and sewerage districts, by which the needs and uses of neighboring communities can be reconciled; arranging for the better disposal of sewage and industrial waste; and in rural districts encouraging better sanitation.

Chemical, physical, and biological analyses of the water in the basin have been few, and are badly needed.

The situation calls for State legislation, where necessary, to give health departments supervision over water supplies, sewage and industrial waste in the interests of public health; for the creation of State agencies to inventory and allocate intrastate waters; for State laws, where needed, to establish water supply and sewer districts; for interstate compacts in some cases; and for the pooling and correlation, by State and Federal agencies, including the Public Health Service, of information now existing, as well as data to be secured by comprehensive surveys.

Erosion Control: It is only in comparatively recent years that the menace of soil erosion in the Mississippi Valley has been generally realized. Yet a large portion of the agricultural land in the basin has lost from 3 to 6 inches of top soil, and "no less than 25 percent of the tilled lands, have actually been stripped to the subsoil." About 5 percent has reached the gullying stage, and have been permanently ruined for agricultural use. Four hundred million dollars a year is a conservative estimate of the tangible loss in the United States.

Erosion is insidious: The first stage is sheet erosion, often so imperceptible that the effect can be detected only by changes in the color of the soil or by an otherwise inexplicable lowering of productivity. Next comes "shoestring erosion", and finally gully erosion, like the last stage in an incurable disease. In the arid regions, and in seasons of drought in the normally humid areas, the wind may be an eroding agent: Witness the clouds of dust which were carried last spring from the Mississippi Valley over eastern seaboard cities. The very land is dying. Measured by man's brief generations it is losing forever its ability to produce food.

Meanwhile living standards on the afflicted land have dropped, farm tenancy, tax delinquencies, bankruptcies and land abandonments have increased, and once smiling regions become a desolate testimonial to man's folly.

Progress in erosion control may be measured by the 18,000,000 acres of farm lands terraced between 1915 and 1932, and by the large number of farmers who have been induced to use such measures of soil protection as improved tillage, crop rotation, and strip-cropping. But it has become apparent that soil protection cannot be left solely to education and self-interest. A national policy and program is imperative.

Public agencies should not be expected to do all the work but unless they intervene it is apparent that the work will not be done, or will not be done in time. Because the emergency is national the National Government must take the lead.

The cost of protection against erosion is but a minute fraction of the cost of erosion. A twenty-year Federal program, calling for joint action with States, counties, land districts, and individual owners, would cost the National Government $20,000,000 a year—5 percent of the measurable annual loss from erosion at the present rate.

III. Water on the Land

If the water resources of a region are to be planned for effectively, there must also be coordinating planning for the land resources. Therefore it has seemed essential to the committee to consider as relevant to water uses problems of agriculture, including irrigation, of forestry, and, because man is not exclusively a working animal, of recreation and the conservation of wildlife. We come again on a maze of interrelated elements, no one completely independent of the others.

Land, Water, and the Farmer: American farm practice, as it relates to the continuing productivity of the land, is now not merely an individual concern—it is a national concern.

Given the existing markets, agriculture has been much overexpanded, even though not much more than one-third of the tillable soil which would be available under such extreme pressure of population as exists in China is now devoted to harvested crops. Fewer farmers and farm laborers are at work than was the case a generation ago, but this diminished number produce more than can be domestically consumed or exported. These generalizations, true of the whole country, are especially pertinent for the Mississippi Valley—the Nation's granary.

Improvements in farming technique have not protected the land itself, as the erosion situation shows. The diversified cropping system of the pioneers was easier on the land, if harder on the pioneer. We cannot return to pioneer conditions, but we probably should return to diversification, which in turn would mean a better balanced agriculture.

A successful national agricultural policy would require that all our soils (of which there are hundreds of types) be analyzed and grouped; that from these studies the best uses of each kind of land be determined; and that scientific cropping systems be developed for each type of land. Local, State, and Federal Governments should unite in this program, preferably through a national body which would obtain the active support of the other agencies.

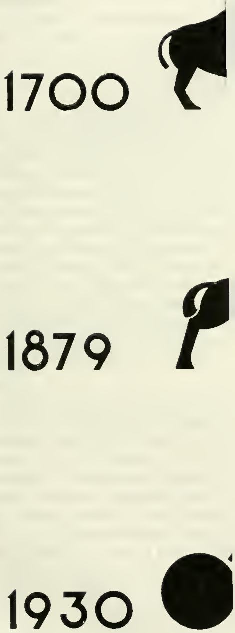
Irrigation: Farming in regions of inadequate rainfall, such as that part of the Mississippi Valley lying west of the one hundredth meridian, demands a special technique on the part of the farmer. The dry farmer, taking his chances with the weather, is relatively independent. The irrigation farmer must usually resort to collective action to bring running water to his land. The semiarid regions, in which the rainfall hovers around the marginal line of 15 to 20 inches annually, furnish a special problem, since their crops may grow without irrigation in rainy years and fail disastrously in dry years.

Irrigation in the American West was practiced to some extent in prehistoric times. White settlers employed it in New Mexico toward the end of the seventeenth century and in California a hundred years later. In modern times it had its greatest expansion after the passage of the Federal Reclamation Act in 1902, empowering the Federal Government to build reservoirs and canals on public lands. At the time of the last census only 14 million out of 168 million crop-bearing acres in the 17 Western States were irrigated of which 5,000,000 acres were in the Mississippi Basin.

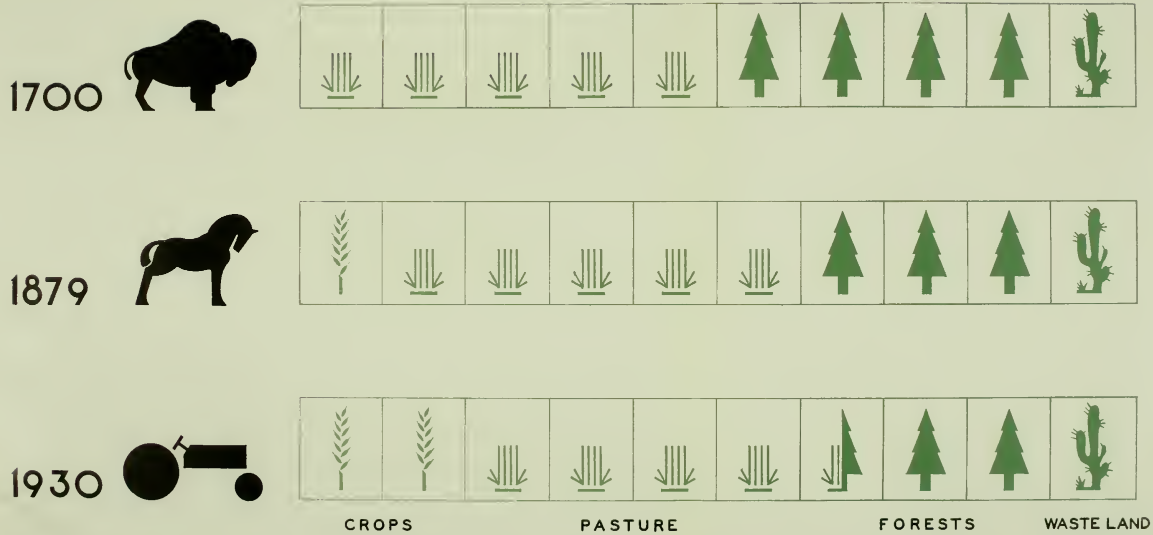
About one-third of the Western irrigated lands is controlled by individuals or informal partnerships; another third is supplied through cooperative or mutual enterprises; about one-sixth is served through irrigation districts; Federal irrigated lands account for about one-tenth, and the small remaining fraction is dependent on commercial irrigation systems.

The costs vary widely. The average for all irrigated lands in the United States is $68 an acre for capital investments, in the Mississippi Basin only $25 an acre. Whatever the auspices under which irrigation is undertaken some system of long-term payment usually has to be arranged. Irrigation, on public as well as private lands, has been the ruin of many a farmer who started out with insufficient capital or who could not keep up his cash income. Nearly every private irrigation enterprise has been in difficulties at one time or another, and on the Federal projects it has been necessary to extend the time allowed for repayment of capital charges from the original 10 years to 20 and finally to 40 years.

Neither the agricultural situation as a whole nor the situation on the irrigated lands justifies Federal action to extend the irrigated area. Where necessary, however, steps should be taken to protect investments in irrigation works and irrigation farms from deterioration. Irrigation should be studied in connection with the recommended national program of land uses. Particularly should there be more accurate estimates of costs and profits. These studies should include irrigation practice in the ordinarily humid regions of the East and South,


1700
1879
1930

LAND USE IN THE UNITED STATES



EACH COMPLETE SYMBOL = 200,000,000 ACRES

where a supplementary water supply has been found useful for producing certain crops on individual farms. In Arkansas and Louisiana, for example, about 161,000 irrigated acres are devoted to rice culture.

Supplementary irrigation of this sort may be aided by the use of electric power for pumping during the off-peak night hours. Natural lakes, ponds, streams, and subsurface waters not available by natural flow may thus be economically utilized. In regions where natural ponds and perennial streams are scarce the wet-season flow might be conserved in artificial ponds or reservoirs. It is believed that detailed cost studies would justify this experiment.

Forestry: "The history of the American forests has been one of exploitation, depletion, and, on large areas, actual devastation." Fires have supplemented shockingly wasteful methods of cutting as agents of destruction. In the Mississippi Basin about 40 percent of the land was originally forested. Only about 20 percent is now rated as forest land, and of this a large portion consists of cut-over land or second growth of little or no present commercial importance. Eighty percent of the forest areas of the entire United States is privately owned, and nearly 50 percent is held by commercial owners, who for various reasons have been slow to apply the principles of scientific forestry to their properties. About 25 percent is still without adequate fire protection. Private ownership, as a means of maintaining the forests in productive condition, has broken down.

The National Forests, about 25 percent of which lie within the Mississippi Basin, now include 165,000,000 acres. Forest lands acquired by 31 States and by a considerable number of counties and towns have reached a total of about 11,000,000 acres. As the result of a recent survey of the situation the Forest Service has recommended that about 225,000,000 additional acres of forest be brought under public ownership—about 60 percent by the Federal Government and about 40 percent by the States and local governmental units.

The mere acquisition of public forests is admittedly not enough. Cooperative protection from fires, insects and diseases; scientific planting programs; erosion control; more equitable systems of taxation; public credit for the improvement of private lands; continuing research; and a general economic survey of forests should be parts of a national forest program. A permanent policy of regulation for privately owned forests, embodying some of the provisions of the N.R.A. Lumber Code, should be adopted. In return for public assistance of the nature described private owners may justly be required to maintain their holdings with due regard to the public interest.

The cost of the procedure recommended by the Forest Service would be about $47,000,000 a year for 20 years for the acquisition and improvement of forest lands, and about $27,000,000 a year for 20 years for other purposes. This national plan would be well adapted to meet the regional needs of the Mississippi Valley.

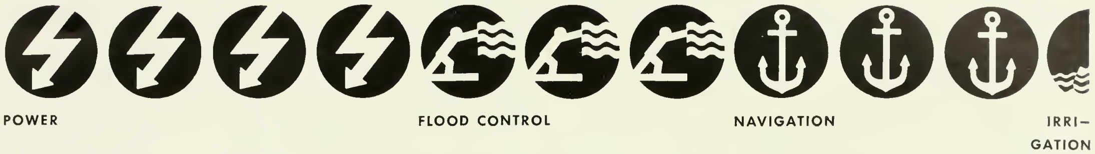
Recreation: Year by year recreation is becoming a larger factor in any plan for land and water uses. Commercial recreation, in city and country alike, has become a major industry, but it does not meet all the needs of all the people. Public recreational opportunities are offered in the National Forests, in the 6,000,000 acres of the National Parks, in the 6,000,000 acres of State parks and forest preserves, in the many State and national wildlife preserves, and in numerous city parks and a few county parks. But these opportunities should be greatly enlarged. In particular, the possibilities of a recreational byproduct of any development of water uses should be studied. Recreation is a necessity, not a luxury. It should have parity with other necessities.

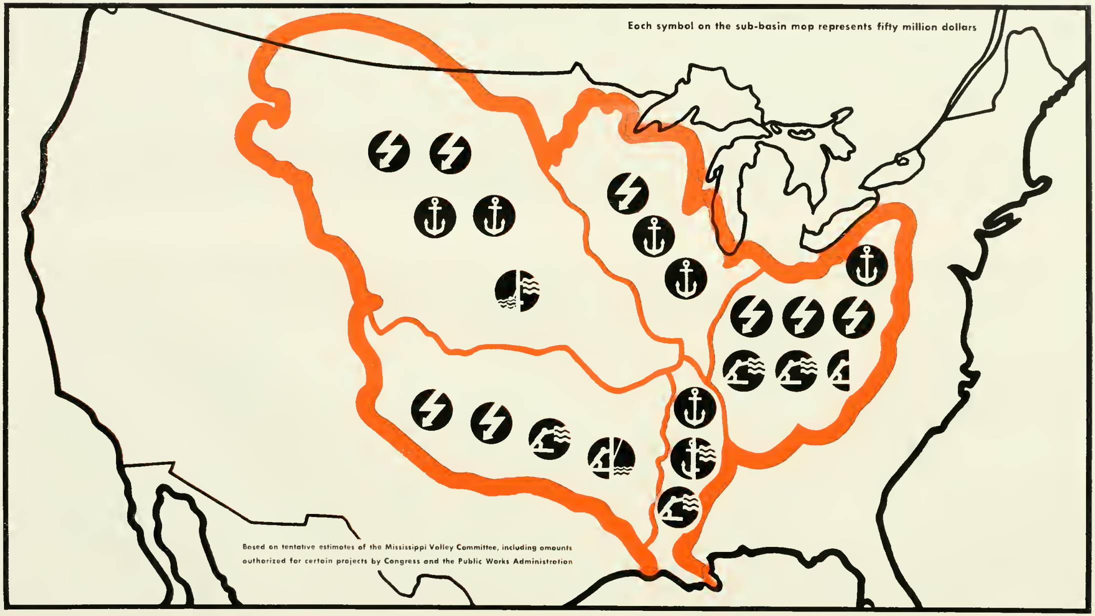
A national recreation policy, adapted to the Mississippi Valley but applicable everywhere, should include a comprehensive examination of all recreation problems and areas; a definite distribution of responsibility between the Federal and other governmental agencies on the one hand and private interests on the other; the coordination of such Federal activities as touch on recreation; the extension of "wilderness areas"; the recognition of recreation as a motive for acquiring new Federal lands not suitable for National Parks or National Forests; provision for new National Parks where the proper standards can be met, and for additions to existing Parks; and, in general, more liberal appropriations for recreation in the Parks and Forests.

Wildlife Conservation: Wildlife has been increasingly depleted with the increase and spread of population. Excessive killing and the destruction of natural habitats have been jointly responsible. In recent years, however, the cause of conservaton has been advanced by private associations, by civic organizations, and by scientific and educational institutions. State and Federal legislation has been improved and an intelligent public opinion stimulated.

COST OF A POSSIBLE TWENTY YEAR PROGRAM

FOR THE ENTIRE MISSISSIPPI VALLEY • EACH SYMBOL REPRESENTS ONE HUNDRED MILLION DOLLARS





Each symbol on the sub-basin map represents fifty million dollars

Based on tentative estimates of the Mississippi Valley Committee, including amounts authorized for certain projects by Congress and the Public Works Administration

Wildlife is public rather than private property. A wildlife program for the Federal Government should include the acquisition of refuges and preserves, as recommended early in 1934 by the President's Committee on Wildlife Restoration; larger appropriations for conservation activities; common action of all water-use agencies with the Biological Survey to protect migratory waterfowl; an enlarged research program; education; leadership in suppressing diseases and other dangers to wildlife; and liberal financial support for the protection of the inland fisheries.

IV. The Great Basins

So far we have been considering the problems of water uses and related land uses insofar as they are applicable to the Valley as a whole. If we subdivide the Valley into five Basins or Regions we find that each has problems which make it desirable to treat it as a unit. These regional problems, however, should be looked at against the background of the general water problems of the Valley. Of these, erosion has already been treated.

The situation with regard to rainfall and run-off and ground water and the water table may be briefly indicated.

Rainfall and Run-off: Probably nowhere in the world within a comparable area is there more diversity in these respects than is encountered in the Mississippi Valley. West of the general line of the one hundredth meridian the climate is normally arid or semiarid; East of that line it is normally humid. Area for area the Ohio Valley has twice as much precipitation as the Valley of the Missouri. In drought years like 1934 the arid climate may temporarily sweep far Eastward into the very heart of the Valley. There is no reason to believe, however, that over long periods, the average precipitation either decreases or increases.

The amount of run-off varies with the rainfall, the amount and character of the vegetation, and the nature of the soil. For the Valley as a whole less than half the water precipitated as rain or snow is carried to the sea; in the Great Plains region the proportion may be 20 percent, or even less, while East of the Mississippi it averages between 35 and 45 percent. West of the Mississippi half the annual precipitation occurs during the four months from April through July; in the Eastern part of the Valley it is more evenly distributed. The flood season fortunately varies in different sections of the Valley, but melting snow and Spring rains make the months from December through April the most critical in this respect.

Ground Water and the Water Table: The "ground water table" is the name given to the level at which water normally lies beneath the surface. A fall in the water table is a serious matter for any population which depends, as probably 95 percent of the population of the Mississippi Valley outside the larger cities does, on subsurface water.

There is no conclusive evidence that a serious decline in ground water levels has taken place generally in the more humid parts of the basin. On the other hand a progressive decline has taken place in North Dakota, the Eastern part of South Dakota, Nebraska, Kansas, Western Minnesota, Western Iowa, and Western Missouri. The new evidence for this decline is based on a questionnaire to which 1,482 well drillers in the sections mentioned sent replies. The data indicated that during average periods ranging from 10 to 44 years there has been a ground level drop of more than 10 feet in Nebraska, Minnesota, Iowa, and the Dakotas, and of somewhat less than that average in Kansas and Missouri.

Averages, of course, tend to conceal the seriousness of some local situations. Large areas in the Western part of North Dakota show a drop of more than 20 feet; in Minnesota the decline ranges from 10 to 20 feet, in South Dakota from 10 to 35 feet, in Nebraska from 10 to more than 20 feet, on the Missouri-Mississippi divide in Iowa from 20 to 30 feet. The diminishing flow of artesian wells, due to wasteful methods of construction and maintenance, led the Legislature of North Dakota to pass an artesian water conservation law as far back as 1921. Some benefit has already resulted, but the artesian water head in North Dakota has fallen at the rate of a foot a year for the past 18 years. In South Dakota there has been a drop of at least 40 feet in 20 years.

The water level obviously depends on the amount of rainfall (although because of underground movements rainfall in one region may affect water levels in another), on changes in surface conditions allowing more or less water to sink into the ground, and on the amount of withdrawals. In most of the States mentioned the fall of the water table has been accompanied by the lowering or drying up of springs, ponds, lakes, and streams.

Since there is no known way of increasing the rainfall, ground water should be conserved by economical use and added to by methods of cultivation that will diminish the direct surface run-off. Conditions undoubtedly warrant an immediate and comprehensive investigation to determine the critical facts for those portions of the basin where subsurface water resources are of paramount importance.

The Upper Mississippi

The Upper Mississippi Basin is that part of the Mississippi Valley lying North of the mouths of the Ohio and Missouri. It includes about 15 percent of the land area of the Valley. Because their economic problems are similar the present study includes parts of the Hudson Bay and Great Lakes basins. This enlarged area has a population a little less than that of the Ohio Valley and a little less than one-third that of the entire Mississippi Valley. Its percentage of land in crops is nearly twice the average for the United States. It produces 80 percent of the nation's iron ore, 11 percent of the coal, 10 percent of the copper, and 16 percent of the manufactured goods. Obviously the latter figures would be greatly reduced if the Great Lakes drainage area were excluded. The economic culture of the region is high but, as the economic map in the body of the report shows, very unevenly distributed.

Water is an important but not a dramatic factor. The land is fairly level; parts of it, in Illinois particularly, form one of the most nearly level areas in the United States. The ice age left thousands of pockets in northwestern Wisconsin and northern Minnesota, accounting for 13,000 existing fresh-water lakes and numerous swamps and marshes. Almost the whole region lies in the humid belt, with a rainfall ranging from 18 inches in the northwest to 42 inches in the southeast. The drought of 1934 upset these averages and in some sections caused considerable losses. The northwestern section lies in an area in which the ground-water level has been seriously lowered. Navigation projects on the Upper Mississippi system have cost the Federal Government, to June 1934, a total of more than $126,000,000 for construction alone, to which the completion of existing projects will add another $91,000,000. At the present no strictly economic justification can be found for this expenditure; it is possible that the future will tell a different story. The water-power potential is not high. Listed projects indicate a total of about 800,000 kilowatts. Drainage is a serious problem in the flat lands of the valleys of the Red River and the Illinois River. Because of the sluggish flow of most of the streams water supply and sanitation present grave difficulties. As an outstanding example, the city of Chicago, drawing its domestic water from Lake Michigan, is hard put to it to dispose of its sewage and waste. The disposal of industrial waste is a knotty problem also for St. Paul, Minneapolis, and numerous lesser cities.

Erosion is at work throughout the region, with an especially serious situation in an area extending from southwestern Wisconsin to northeastern Iowa, and from southwestern Minnesota to northwestern Illinois; and in a second area in southeastern Iowa and northeastern Missouri. Floods are usually local in character, doing damage in the wet and poorly drained valleys. Heavy losses are sometimes caused when the Illinois River levee system breaks. These levees should be set back and strengthened and much of the now cultivated bottom land set aside for reforestation, bird refuges, and reservoirs.

The economic culture map indicates that prosperity in the region is decidedly spotty. Sometimes undrained marsh lands, drought, erosion, or a lowered water table may be responsible for a low economic status. The decline of the copper industry or the competition of cheap oil and gas with the local coal supply may cause an economic recession, as in two instances in this area. In some areas the draining of infertile lands has proven to be an economic blunder of the first magnitude.

The bright side of the picture is that constructive planning is already under way more or less effectively in all the states of the region, notably in Wisconsin and Minnesota. No new projects calling for Federal participation are recommended, but the Committee believes that a unique opportunity exists for Federal, State, and local participation in a general regional planning program which might serve as a model for other areas.

The Ohio Basin

The Ohio River contributes to the Mississippi a minimum flow of 25,000 cubic feet per second, a maximum flow which has gone as high as 1,500,000 second-feet, and a normal flow of between 250,000 and 300,000 second-feet. On the average its flow is more than one-half that of the Mississippi below Cairo. Rarely do its waters fall so low as to hinder navigation or other necessary uses. At long intervals, usually a generation or more apart, it sends down huge and destructive floods.

The area of the Basin is about one-sixth of that of the Mississippi Valley, its population more than one-third that of the Valley, the living standards of its people equal to or a little above the national average. Its annual

1,250,000 c.f.s. – (Jan. 1937)

gricultural product, amounting to about two illion dollars, supports a farm population of out five million people. Its manufacturing tput is more than four times as great. In neral the industrial centers are north of the hio River, and the highest living standards ist there. South of the Ohio the predomantly rural section has a considerably lower ndard of living.

We have here the regional phases of many of e general problems of the Mississippi Valley—ose having to do with arid conditions expted. Complete flood control of the main er is difficult if not impossible. Effective ntrol on some of the tributaries is perfectly sible. In the body of the present report a gram is suggested for thirteen new flood-control projects, in addition to the two already approved. The total cost of these fifteen projects would be $117,000,000, of which it is suggested that the Federal Government furnish about $61,000,000. Further surveys are needed, both for flood control and for low-water control.

The extensive use of the Ohio system for navigation is indicated by the fact that the Monongahela alone leads all the inland rivers of the United States in traffic, and that the Ohio itself carries more than the Mississippi. Coal, coke, sand and gravel, iron and steel, and petroleum are the principal commodities carried. With costs to the Federal Government for improving and maintaining channels ranging from one mill for each ton-mile on the Monongahela to 23.2 cents per ton-mile on the Big Sandy it is clear that some of the river improvements in the Basin have justified themselves and that others have passed their peak of usefulness. There is a middle group whose future status should be determined by further inquiry. It is suggested that a study be made to determine if it would be practicable to levy shipping charges for the special services and facilities now provided at government expense. New navigation projects may well wait such determination.

The Ohio Valley will probably double its demands for power within the next 20 years. That is to say, it will probably need in 1955 about twice the 17 billion kilowatt-hours consumed in the peak year of 1929. At present only 14.8 percent of its installed electric generators are waterdriven. Since the Basin contains large coal deposits water power must meet keen competition, and it seems better to wait further developments, including those now being made by the Tennessee Valley Authority, before making recommendations for specific power projects on the Ohio and its tributaries.

Erosion is at work in the Ohio Basin as it is elsewhere in the Great Valley. Four demonstration stations have been established by the Erosion Service within the Basin and work is being done by C.C.C. units in filling up gullies. Beyond these undertakings erosion control must await the carrying-out of the urgently needed national program.

Water supply has been a problem this year in parts of the Ohio Valley, but more urgent is the question of the disposal of sewage and industrial waste. Planning for the future should balance the demand for "quality water" for domestic use against quantity demand for flushing sewers and carrying away factory waste. The Federal Government should extend its surveys of streams and other sources and help in educating the public in the need of protecting water supplies and preventing pollution.

The Basin is lacking in natural lakes and ponds but otherwise offers many facilities for recreation—not without reason did the French call the Ohio the "Beautiful River". Here, as elsewhere, the recreational purpose can and should be combined with power, flood control and navigation projects. An example worth imitating is that of the Miami Conservancy District, where a total area of between 1,500 and 2,000 acres, in tracts adjoining four dams, has been designated for public use as camping and picnic grounds.

The Missouri Basin

Exceeding in size the combined areas of Germany, France, and Italy, the Missouri Basin has 43 percent of the land in the Mississippi drainage area but only a little more than 15 percent of the population. It contains parts of four of the major physical divisions of the United States: the Ozark Plateau, the Central Lowland, the Great Plains, and the Rocky Mountains.

In the Eastern third of the Basin are found most of the population and nearly all the large cities and manufacturing industries. Forty percent or more of this zone is normally cropped with winter wheat and corn dominant in the South and spring wheat in the North. With certain exceptions the soil is fertile and agriculture is relatively stable.

West of this section lies the great middle zone, a true "Land of Little Rain", in which cities are few and small, and where the agricultural front has been held at great hazard and often with heavy loss. The dry farming and irrigation farming problems of this region are many and the solutions still seem far ahead.

The third and westernmost zone includes the foothills and ridges of the Rocky Mountains and adjacent plains. Here, on the Eastern slopes of the Continental Divide, mining and irrigation agriculture have produced "islands" of growing population in the sea of sparsely settled mountainous areas and semiarid plains. The petroleum industry, probably now near its peak in this region, and the coal industry, with most of its probable development still ahead, are factors making for growth.

Water, whether as a flood menace or as the very lifeblood of the region, is a vital factor in all three zones. Flood control is a problem in the headwater areas and in the Kansas River-Lower Missouri area. The flood problem in and around the two Kansas Citys is the most serious in the Basin and one of the most serious in the United States. High water here may paralyze one of the nation's chief transportation centers. The feasibility of local levee protection seems doubtful. The Kiro dam is considered impracticable. It is recommended that an immediate technical and economic survey be made cooperatively by Federal and local interests in order to determine the practicability of controlling floods on the Kansas (or Kaw) River, and that steps be taken to form an interstate conservatory district which may participate with the Federal Government in any flood-control measures undertaken.

It is estimated that about 950,000 acres of land, capable of supporting a farm population of about 75,000, might be reclaimed in the Missouri Basin through irrigation. Certain of these projects should be studied, with the Federal Government bearing half the cost of the surveys and participating in whatever enterprises may be found worth while. Other irrigated areas which are suffering from serious water shortages require supplemental works. In general, however, a further extension of irrigation cannot be expected to contribute in a large way to the general welfare of the Basin.

A regional regulation of streams to insure a dependable domestic water supply and guard against pollution is desirable. Denver and its neighboring communities are now facing a water shortage, and in the Dakotas, as has been pointed out, there has been a marked and disastrous drop in the water table. Although the project to divert flood waters of the Missouri into North Dakota is not feasible, it is recommended that the Federal Government bear part of the cost of surveying and constructing stream regulation works for groups of communities which will organize responsible conservancy districts. The Government should also encourage the drilling of deep wells which in the Dakotas should afford some relief in times of water scarcity.

Although large sums have been spent in improving channels along the Missouri system the commercial usefulness of the river has not been great as yet. Until the value of further improvements, costing about $250,000,000, is determined, no further projects are recommended. It is recommended that the Osage River project be abandoned.

The undeveloped water power in the Basin is estimated at 2,110,000 kilowatts. No water-power projects are recommended for present development, but it is urged that power sites on Federal lands shall not be allowed to come under private ownership. Attention is called, however, to an apparently exceptional opportunity for cooperatively planned social betterment in the Black Hills Region, through the medium, in part, of an abundant supply of low-priced power. A proposed "mouth of the mine" steam plant at Gillette, Wyoming, may be able to furnish the required power. A thorough technical and social investigation of this possibility is earnestly recommended.

Recreational facilities are abundant on the slopes of the Rocky Mountains but are relatively restricted on the Great Plains and Eastern Lowlands, and in the latter areas it is particularly desirable that they should be developed in harmony with the national policy already outlined.

In the body of the report six project areas in the Basin are discussed. In these, multiple-purpose planning should be considered, with attention to the social and economic needs of the people as the key to whatever is done.

The Southwest Basins

The valleys of the Red, Arkansas, White and Ouachita Rivers, containing more than one-fifth of the total area of the Mississippi Valley and having only about one-sixth of the population, are still underpopulated. They offer pioneering opportunities hard to find in any other part of the United States. Not only is there much good agricultural land, but the basins are rich in gold, silver, petroleum, and other underground resources. Almost every kind of crop can be produced somewhere in the region, with the Arkansas Valley marking the Northern boundary of the cotton belt as well as "the boundary of cultures where North and South meet."

Hydroelectric developments in the steep western reaches of the rivers will be of great importance in developing the whole territory. At the same time there is a need for flood protection in the form of levees, channel improvements, spillways or reservoirs further down. In the Western portions of all four rivers the water supply requires to be conserved; in the Eastern portions it must be regulated and controlled.

Flood control is a serious problem on the Red River below Denison; along a large part of the channel of the Arkansas; on the lower stretches of the White, which are subject to backwater flow from the Mississippi, and in the Ouachita Basin, which in flood time may receive backwater or overflow from the Mississippi, the Red, and the Arkansas.

Water-power developments in the region face competition from steam power produced cheaply from coal, oil, or gas. At the same time the fact that nearly half the population lives on farms and that only five percent of the farm homes use electricity indicates one large potential market for power. Six hundred thousand horsepower could be developed along the Red River system; the Arkansas is still wholly undeveloped along its main stem; the White River can produce about three-quarters of a million horsepower; and there are partly exploited possibilities on the Upper Ouachita.

Navigation is possible on all four streams for varying distances, and a considerable amount of Federal money has been spent on channel improvements, but the actual use made of these facilities is minor and no further improvements are recommended. Irrigation is important on the western stretches of the Red and Arkansas Rivers and in lower sections of the Red River devoted to rice culture. A thorough study of potential water supply and sanitation requirements is recommended in order to meet the needs of the growing population. Forestry is important chiefly in the Eastern section, and much ol the best forest land has been cut over. Outdoor recreation has been inadequately provided for, and should be included in any comprehensive plan for the development of the Southwest Basins

In the body of the report will be found a classified list of projects for power, navigation, irrigation, water supply, and recreation. From this list it will be possible with little delay to select projects which are consistent with the general plan of Mississippi Valley development as conceived by the present committee.

The Lower Mississippi

The Lower Mississippi Valley contains something more than one-twelfth of the population of the Mississippi Basin, and its area is somewhat over one-twentieth that of the entire Basin. Sixty percent of the population live in the Alluvial Valley or Delta, and 40 percent in the uplands. The lowlands are fertile and capable of supporting a far larger population than they actually do; the uplands are perhaps overpopulated in proportion to their resources.

In both sections about two-thirds of the population is rural and about half depends directly on agriculture. The key to the future of the area as a whole lies in the Alluvial Valley, and the key to the future of the Alluvial Valley is dependent on the solution of the flood problem. Further economic—and, it may be added, social—developments there must of necessity be restricted for the most part to be protected areas. Under the Adopted Plan for Lower Mississippi flood protection about half the Delta area is now safe from the waters of the main river. The Federal Government, which provides the protection, has a vital interest, as it has a vital influence, in the nature of the economic and social life that its work makes possible.

The protected lands of the Delta should be capable of supporting a highly prosperous rural society; actually cash incomes are strikingly low, living conditions are substandard, and farm tenancy has increased until about 80 percent of all farm operators now are tenants. If new Delta lands are to be developed and protected a program should be worked out, under Federal auspices, which will enable farm operators to acquire ownership and which will raise the general standard of living.

If we consider types of land areas in the region as related to water problems we find erosion in the uplands a critical factor, with conditions and proposed remedies similar to those described earlier in the present summary. In the protected Delta lands drainage involves serious difficulties—so serious, indeed, that a third of the land now protected from all floods still remains unoccupied. There is an abundant water supply, but pollution and the disposal of sewage are problems in many areas. Navigation on the tributary streams is of slight importance, despite costly channel improvements. Navigation on the Mississippi itself has been declining since 1926. In view of the fact that the Federal Government has spent or authorized the spending of about $190,000,000 for improving the channel between New Orleans and Cairo an inquiry as to whether or not shippers should bear a portion of the cost is highly desirable.

Flood control on the main river involves: the levee system, now more than two centuries old; recent experiments with floodways, into which flood waters not containable within any existing or conceivable levee system may be automatically diverted; attempts at channel stabilization; and an expenditure, since 1928, of more than $300,000,000. The system of "fuse plug" levees and projected spillways brings up questions of equities in the lands which would thus be flooded; these questions should be settled with as little delay as is consistent with fairness to all concerned and a definite floodway policy and program entered upon.

Three specific projects, in the Yazoo Basin, in the St. Francis Basin, and in the Black River Basin, are discussed in the body of the report. It is recommended that studies for the development of these areas be commenced at once. "The time is ripe to initiate a new, more comprehensive and enlightened system of land reclamation and community planning designed to secure ultimately to the settlers an improved standard of living."

The protection of land involves the protection of the people, and the protection of the people stops short of its proper objective if it does not lead toward what sociologists call the "good life."

Interrelation of Interests

As communities increase in population, extent and complexity new and far-reaching agencies have to be called in or created to deal with their water problems. The family well gives way to a city water system, that in turn, perhaps, to a district or sectional water system. In time, as the present report suggests, a national program is required to reconcile the needs of the 49,000,000 people who live on the 1,235,000 square miles of the Mississippi River System. The multiple uses of water add to the intricacy of the problem.

There consequently should be a revaluation of controlling agencies, both local and general. Where the physical problem to be attacked transcends existing political boundaries, new types of regional organization, such as the New England Council or the Ohio River Board of Health Commissioners, have already appeared. Other types are the "Authority", or publicly owned corporation, of which the Port Authority of New York is an example; the intrastate conservancy district; agencies set up by two or more states under interstate compacts; and Regional Authorities set up by the Federal Government, for which the Tennessee Valley Authority may be regarded as a precedent.

Either on its own initiative or on request from the States, the Federal Government should stand ready to investigate projects or situations. In planning and carrying out actual operations the benefits and responsibilities should be as accurately assessed as possible as between the National, State and local governments. The Federal Government's responsibility should not be too narrowly interpreted, since it is in practice and by the terms of the Constitution accountable for the general welfare. Measurable benefits are not always the only criteria which can be set up. "The ideal allotment of costs will be that which will produce the best total economic effect within the limits of public support and of administrative practicality, with due regard to all equitable considerations."

The final criterion is that of public support. There should be, and invariably is, a constant flux and interplay between Federal guidance and spontaneous local activity. An emergency such as a flood or even the swift and deadly processes of erosion, may require instant action by whatever agencies are most effective. When quick action is not imperative, as in the acquisition of new lands for parks, the approach should be through an education of the popular will. Governments, national or local, should not attempt the impossible, nor can they safely go against the grain of public opinion—whose servants, in a democracy, they are. Sometimes situations will develop for which there is no governmental remedy; these situations should be recognized as such, however painful the realization. Policies making for industrial decentralization and local self-sufficiency should be outlined and encouraged wherever they do not act against the general welfare.

"Above all, the Federal Government will need to make clear to the people that its function is not to take over the direction and responsibility for individual enterprises, but to provide these physical and economic adjustments that will lead to a generally favorable environment in which local enterprises may operate."

Planning

The words "plan" and "planning" have grown to have a precise meaning for engineers and industrialists, expressing definite objectives and definite ways of attaining those objectives. The only assumption with which they have been loaded in the present report is one which ought to be held as self-evident in a democratic society, that no social or economic technique is sound which does not make for the health and well-being of the people.

Industrial and engineering practice distinguishes three "planes" of planning; directive planning, which defines major purposes, ways and means; general administrative planning, which carries out in the individual plans or project the policies of directive planning; and operative planning, which determines detailed operations. Similarly the steps in planning include an original definition of purpose; the adoption of policies, which represents an adaptation to the human and material factors which must be dealt with; the formulation of a program or tentative chart of operations; and a final design, in which precise qualitative, quantitative, and functional relationships are established. This done, the final plan may be subdivided into projects.

That these proven principles of private planning may be adapted to governmental planning the Committee is convinced; that anything less than planning of this nature will suffice to meet the nation's needs is extremely doubtful.

The principles outlined permit both the long-range view and the early preparation of specifications for particular projects which may be entered upon at once, or which may be kept ready for some future time when a large amount of unemployment exists. Both the enactments of the Congress and current public opinion suggest that desirable public works should be so used as a means of balancing employment both in good times and bad.

Practically all varieties of public works involve design and require detailed specifications before construction can begin. Hence it is strongly urged, as good public policy, that on improvements that are reasonably sure of being ultimately built, detailed plans and even specifications be promptly carried as far as practicable. For instance, borings for dam sites should be undertaken as soon as it seems likely that a given dam will in time be built. After this policy has been in force for some time the need for emergency employment can be met much more expeditiously than is now possible.

It is hardly necessary to point out at this stage that the general planning of the use and control of water resources must rest with the Federal Government as being the nearest we can come to an expression and reconciliation of the various purposes and desires of all our people and all our governmental agencies. In adapting an industrial technique of planning to the needs of the nation we would not be violating the principles of democracy and local self-government; we would merely be giving them a new tool.

The present plan is neither complete nor final. It is necessarily selective and in many ways tentative. The Committee has sought to combine a broad and long-range view of the problems of the Mississippi Valley with definite proposals for doing certain things that ought to be done at once. The sooner certain projects arrive at the blue-print stage the better for the public welfare and safety. The plan as a whole is not a blue-print. It is rather an attempt to indicate desirable lines of growth. The plan will have best served its purpose if it, too, grows, changes, and improves as the years go by.

SECTION II

USE AND CONTROL OF WATER IN STREAMS

USE AND CONTROL OF WATER IN STREAMS

Introduction

At the outset it should be fully recognized that planning for the most beneficial utilization of the water resources of the Mississippi Valley requires that the region be viewed as an integral part of a continent as well as by itself as an integral whole; that development of water resources must be related to development of other physical resources; that development of any phase of the water resources must be considered in relation to all other phases; that physical factors must be evaluated in terms of cultural and economic conditions and influences; and that these influences must be appraised not merely in terms of today but of present trends and our vision of the future.

Logical planning for any one phase necessarily means planning on a much wider front than for that phase alone. It means planning for all factors in our social and economic environment directly or indirectly to be affected. For the planning concept is based on recognition of the fact that things are related to each other; that functional developments, like water use and control, are related to other functional activities or developments; that developments in one area are related to developments in contiguous and sometimes even in remote areas.

Whether the subject be flood control, low-water control, navigation, power, water supply and sanitation, erosion, irrigation, or other phases of the water problem, each must be considered in relation to all the others and to agriculture, forestry, industry, and commerce.

Only when any one phase of the general problem is so treated, does one discover all its actual and potential power to influence the future of the Mississippi Valley, either positively or negatively. And if undue emphasis be given to any one functional purpose, there are sure to be misfits, wastes, errors, even tragic results by reason of failure to have planned the program without well-balanced evaluation of all integral relationships.

The first approach, therefore, in planning for any one phase of the water problem, is to establish a frame of reference whereby consideration of that particular phase and the resultant plan may be a logical and consistent expression of all the relationships between all the factors involved.

The General Problem

The principal problems of control and use of waters in streams originate in variation and irregularity of flow. The ideal river, which would have a uniform flow, does not exist in nature. In contrast, the flow of the typical stream at any time depends on the combined influences of a vast number of circumstances, many of which are themselves continuously changing. These are the amount and distribution of rainfall, the nature and condition of the soil on which it falls, the vegetation, and the temperature, humidity, and motion of the atmosphere. Few of these influences are predictable, and some are even difficult of measurement or appraisal after they are observed. The stream flow governed by such unstable phenomena is, of course, a variable of great irregularity, an irregularity, in fact, that produces the deplorable floods and droughts by which most rivers are occasionally visited.

If it is borne in mind that use and control of water in streams should begin with elimination of extensive variations of flow or with amelioration of their effects, the broad general problem presented will be clear.

Adequate water supply is a basic requirement for successful habitation. It is the first requisite, in varying degrees, (1) for the establishment of a home, (2) for the development of a community, and (3) for promotion of agriculture and manufactures.

In many sections of the United States, Southern California, for example, limitations of available water supply place a definite check on development of the territory. In other sections, like the Ohio Valley, present and potential water supplies are sufficient for almost any conceivable need. In places where water supply is scarce, its value is clearly recognized. Where it is plentiful, it is commonly looked upon as a matter of course, like fresh air and sunshine. Unlike the two latter resources, however, water supply, even under most favorable conditions, is seldom inexhaustible.

The uses of water need little elaboration. The principal uses (not necessarily in order of their importance) are: for domestic water supply; for disposal of waste; for development of electric power; for industrial purposes; for irrigation; for navigation, and for recreation. The problem of developing available water resources is traditionally a local problem, and, to some extent, is bound to remain primarily so. Water resources, however, do not service one isolated community alone, but are used over and over again, by a succession of communities. Hence, conflicts over the use of available water, for the same or for different ends, may and do develop.

The diversion of water in large quantities for irrigation has, in a number of instances, so depleted the flow of streams that lands of communities and States lying downstream have been seriously injured. In many cases large expenditures are necessary for a reservoir in one state, the benefits from which will accrue largely to another. In densely populated areas the custom of using streams for disposal of sewage and industrial waste brings up problems of the gravest importance for downstream communities, especially if those communities have to depend upon the same streams for domestic water supply. Frequently such cases require legal or other more or less arbitrary adjudication.

Interference by local authority with navigation, has long been recognized as a matter for Federal concern. Policy is not so clearly defined in cases of other types of conflict between the uses of water and some confusion has been the result. Geography is no respector of the rights of States, and unless the confusion is to be increased still further, water use in the Mississippi system must be developed not in accordance with purely local interests, but according to a comprehensive plan.

The problem of control, as distinct from constructive use, of the Mississippi basin waters is even less adaptable to local treatment. Many minor local flood conditions may be handled with entire satisfaction by local authority, but general flood problems, beyond the capacity of local interests to solve, exist in many of the states of the basin. Levees along the lower Mississippi are built to hold within bounds the waters which have been contributed from points as far east as Pittsburgh, as far west as Idaho and from all the land between. Spring thaws on the Monongahela and rainfall in the Dakota badlands have their influence on Mississippi flood conditions.

All these cases point to the need for uniform State laws, as well as some plan for a competent administrative authority, with power and facilities to make all needed investigations to determine fully the facts and equities. Such authority should also be empowered to determine the most equitable solution of every controversy and should be so organized as to be able to put its adjudications into effect.

The problem of how much or how little water, also, takes on a new significance in public works planning. A sound solution requires accurate and unbiased information. Water facts are needed not alone for design and construction to prevent over-development or under-development of the available supply. The operation and administration of completed projects also require precise knowledge, as does the division of water between various users, whose relationships may be international, interstate, or local.

Unlike ordinary surveys, water investigations must continue over a long period of time. In general the flow of streams varies widely from season to season and from year to year. Short-time investigations will not serve for reliable estimates of the maximum, minimum, and normal to be reckoned with in planning.

Neither can statistics from one drainage area be used for dependable estimates of the flow from other areas, even those adjacent. If the planners of future works are to have essential facts, studies must be carried out on a nation-wide basis, so that data on every important stream will be ready when the time comes for development.

Ground water, as well as surface water, requires detailed investigation, not only of the supply from wells, but also of the ground storage where it is a considerable factor. Studies of mineral matter in solution and suspension also are needed to determine the quality of water for domestic or industrial uses and to provide data bearing on the silting of reservoirs.

Flood Control and Water Use

The natural flow of any stream varies ceaselessly. It is governed by variations in rainfall, by the character and condition of the soil, by vegetation, by temperature, and by other factors. Heavy rains swell streams, and so do melting snows; some soils, expecially those which have been badly eroded, shed water rapidly, and other soils absorb a large proportion of the water which falls upon them. Under abnormal conditions the flow of a stream may become larger, for a time, than the capacity of the normal channel. Then it will spread out over adjacent lands within the flood channel, causing extensive damage to farm lands and improvements, to cities and towns, to railroads, and highways, which have encroached on the flood plain, damage which increases in amount with the extent of the encroachment and density of population. Life is often endangered. In a large river system, flood peaks on the principal tributaries do not usually coincide in time, so that the channel is normally able to take care of the flow, except under conditions of a general, long-continued storm.

It is only because of the infrequent occurrence of great floods that flood problems arise in settled communities. If maximum floods occurred every year, the flood channels of rivers would be unoccupied except when accompanied by adequate protective works, and, therefore, flood problems would be nonexistent. Unfortunately, it has become common practice to encroach upon flood plains of rivers without recognizing the potential danger, and for this reason flood damage has to be faced.

The general methods of guarding against or reducing flood damages, include: (1) artificial improvement of natural channels to increase their carrying capacity, including provision of side channels or overbank channels for accommodation of flood flows; (2) confinement of flood flows by artificial works, such as levees; and (3) storage or retarding of flood waters in reservoirs. No one of these methods alone is capable of solving the flood problems of an entire river system like the Mississippi; the solution lies in the use of one method here, another there, and a combination of two or more methods where that best meets the requirements.

The first method, that of improving the natural channel by straightening, widening, and deepening, or providing side channels, is adapted to conditions in which relatively small increases in capacity are required, or to other special cases. The method is too expensive for general application.

The second method, that of restricting the flood channel of the stream by means of levees, is the traditional method and is the one now being generally used on the lower Mississippi. This may be designated as a compromise with the river, for it usually involves restoring to the channel a portion of the flood plain which originally served no other purpose. This form of protection is direct and visible, since the levees definitely separate the areas of safety and of danger. They thus constitute a standing warning against the occupancy and use of the portion of the flood channel which remains exposed.

There have been many advocates of flood control by levees alone, who believe that a river, if protected by levees will scour its own channel through alluvial soil. This belief has little support in theory and none at all in observed fact. The plan now being followed for the Lower Mississippi makes use of a combination of standard levees with low level "fuse plug" levees located at the heads of suitable over-bank side channels. The fuse plug levees, overtopped before the standard levees are endangered, allow the excess flood waters to escape into the side channels.

The third method, that of control by reservoirs, requires that suitably located reservoirs be provided in which flood waters in excess of the capacity of the channels downstream may be stored or retained until they may be released with safety. If the locations and capacities of the reservoirs are suitable and adequate, complete protection against floods may be provided. The reservoirs may be so designed that their outlets, although not provided with gate control, will not permit the discharge of water in excess of the permissible maximum. Such reservoirs are called retarding basins. Outlet structures may, on the other hand, be provided with gates so that rates of discharge may be controlled. Such reservoirs are usually called storage reservoirs even though the scheme of operation may not contemplate detention of water at any time beyond the amount that may be released without inflicting damages downstream. If the capacities of the reservoirs are sufficient, they may be used for long-term storage so as to provide a high degree of regulation, reducing the flood flows and augmenting low water flows either seasonally or over dry years. Perhaps the most striking example of the regulating effects of storage is that of the Great Lakes and the St. Lawrence River. The river is so regulated by the natural storage in the Lakes that its flow ranges between very close limits from season to season and year to year and, as a result, the St. Lawrence is one of the most useful rivers, actually and potentially in the world. At the same time the size of the Great Lakes gives some conception of the storage capacity required to regulate completely a great river. Similar effects on such a scale are not likely to be sought by artificial means, but comparable results may be secured on many smaller streams by artificial reservoirs, if the objectives are sufficiently important to justify the cost.

In a general consideration of flood control by reservoirs it should be borne in mind that the channel of a stream in flood constitutes a very effective kind of reservoir, because it is constantly making room for more water. A storage reservoir to be equally effective would either have to be of much greater area than valley lands under flood or would have to provide storage at greater depths. The former requires availability of reservoir areas of relatively low value, and the latter requires favorable topographical features to afford deep storage economically.

A reservoir for flood protection is most effective if it is not far upstream from the lands to be protected. That is, a reservoir on one of the tributaries to the Mississippi might not give assured protection to the Mississippi itself, because the run-off of water between the reservoir and the area of danger on the Mississippi would be of variable and unpredictable quantity. In short, there is no doubt that the direct effectiveness of a reservoir is increased the closer it is to the area to be protected. Nevertheless, a reservoir constructed and operated for local flood protection on a tributary, often, though not always, decreases to some extent the magnitude of floods on the main river. To illustrate, records show that there have been no major floods in the Mississippi when the discharge of the Ohio at Cairo has been less than 1,000,000 second-feet. The Muskingum flood control project will have a measurable effect in reducing flood crests on the Ohio. Other similar projects might result in a substantial measure of flood control or abatement on the Ohio or the Mississippi.

Navigation is particularly benefited by reduction of flood crests, and all of the possibilities of water use are improved by increases in flow at extreme low stages. Under certain favorable circumstances it may be possible to release water from flood control reservoirs to satisfy requirements for hydro-electric power development at the dam, or to regulate the flow down stream to the advantage of a variety of water uses. In such cases equitable distribution of costs among the several purposes served may even sufficiently reduce the costs chargeable to flood protection to warrant the construction of flood-control reservoirs which could not be justified for flood protection alone.

There is, of course, an apparent conflict between the use of the same storage reservoir for power development and for flood control. A flood-control reservoir should be empty at the beginning of flood seasons, and, if filled, should be emptied promptly in anticipation of another storm. Storage for power, on the other hand, requires maintenance of a head and dictates that water be released only as required by the demand for power. Yet, it is often possible to reconcile this conflict by allocating a certain capacity in the lower portion of the reservoir for power storage and the necessary capacity in the upper portion for flood-control storage. Often this combination would be much more economical than two separate reservoirs. In this connection it should be remembered that the lower portion of a reservoir lends itself favorably to creation of available head without sacrifice of much storage. A 10-foot depth at the bottom of a reservoir corresponds to much less storage capacity than an equal depth near the top. The ratio is often as much as 1 to 12. The sacrifice of 40 or 50 feet of depth at the bottom of a deep reservoir for the development of head for a power plant may be recovered by an extension, say of 4 or 5 feet at the top. Recognizing the opposing requirements, such projects have to be considered on their individual merits in the light of local physical conditions.

The relationship of irrigation storage to flood-control storage in the same reservoir is somewhat different. Irrigation demand usually reaches its peak during the season when flood probability is remote. Therefore a storage reservoir operated exclusively for irrigation usually will be low at the beginning of the flood season. Flood waters, in fact, are the principal source of supply for irrigation storage. Furthermore, water released for irrigation purposes may also be used for power development insofar as power demand coincides with irrigation demand, thus doing double duty. Usually a certain discharge is required through an irrigation reservoir during the entire irrigation season (five to seven months) to satisfy existing rights to natural flow. Furthermore, draft on irrigation storage extends over a considerable time, and is therefore available for power development over an extended and predictable period. In many instances a reservoir might be made to do triple duty, for flood control, for irrigation, and for power development, although this combination would almost invariably involve concessions from one purpose to the other.

A Rational Program

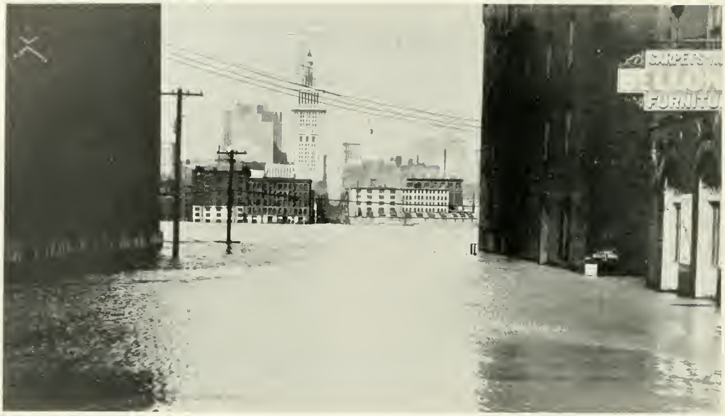
The best plan for control and use of the water resources of a large river system may be expected to employ a combination of the several established methods of flood control. The improvement of the carrying capacity of channels, where they are naturally restricted at vital points, such as important cities, may be undertaken to avoid the need for a higher degree of regulation throughout than would be required with the increased capacity to be provided at such local areas. Levees may be built either for local protection to serve like purposes, or for the protection of wide areas when the cost of other methods of protection would be exorbitant.

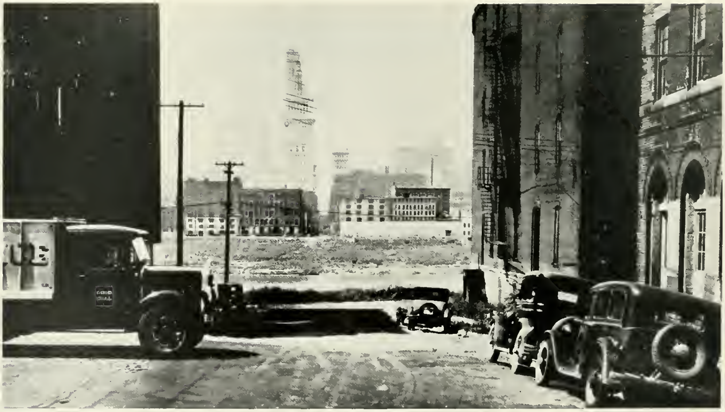
The control of floods and the means for effecting it should be coordinated in a comprehensive plan with the exploitation of the water resources, so that the one may support the other, each bearing its share of the expense and, if necessary, subordinating its lesser requirements to more important needs of other purposes. Since these relations are ever changing, the coordinated plan must also be subject to growth and development. Starting with facts, such as the physical geography of the basin, the population it serves, including their social and politicial organization, the known resources, the development actually attained and that immediately in prospect—in short with all of this information of the governing influences that may be assembled—the plan may provide definitely for the prosecution of projects immediately practicable and those whose early practicability may be confidently foretold. These elements of the plan may be regarded as fixed. Upon that foundation may be erected more flexible features for the longer term future, designed perhaps to modify some of the governing influences or to point new directions for development.

The Broad Scope

Recalling the opening sections of this paper, it is apparent that planning for coordinated water use and control must take into account the interrelation, be it positive or negative, of the several obvious phases—water supply, flood control, power development, navigation, irrigation. But water questions also touch, quite definitely, agriculture, waste disposal, soil erosion, siltation; and in a less direct way (but nevertheless influentially), industry, commerce, stability of population, homebuilding and community development, recreation. In fact, planning as it should be done, for control and use of water in all its phases, virtually is planning for most of the basic functions of the life of the Nation.

A NATIONAL FLOOD CONTROL POLICY





Above, Cincinnati, Ohio, March 21, 1933, with the Ohio River in flood. Gage 63 feet 6 inches.
Below, Cincinnati, July 20, 1934, when the gage was 12 feet.

A NATIONAL FLOOD-CONTROL POLICY

The aggregate losses in the United States from major floods may not be as great as those from certain less dramatic causes, such as soil erosion, nevertheless, flood loss creates a problem which must be squarely faced. A sound basic policy is needed, giving due weight to merit and justification of individual projects, results to be secured, and equitable allocation of benefits and costs.

Consideration of a National flood-control policy must necessarily recognize that the flood-control aspect of a project, be it a major purpose or an incidental one, must be evaluated in the light of a broad study which takes into account all other purposes or possibilities involved. Among such other purposes may be power, navigation, irrigation; may be low-water control, water supply, sewage, or waste disposal. Wherever more than one purpose is indicated, each must be considered in its full relation to all the others. Only by such procedure can a well coordinated project be evolved.

Having thus evaluated the flood-control feature of a project, there remains the need to determine (1) the value to the public of the flood-control benefits as related to the flood-control costs, and (in case the benefits will justify the cost), (2) proper allocation of such benefits, to determine a reasonable basis for financing the flood-control costs.

Benefits Difficult to Estimate

An accurate estimate of value of flood protection, even to a single piece of property, is difficult to make. Floods of sufficient magnitude to damage valuable properties are of comparatively rare occurrence, and reliable records of damage are difficult to obtain. Even where some records are available, the task is complicated by many items difficult to evaluate. Real-estate values are affected by so many things that an estimate of increased property value due to prospective flood protection is apt to be misleading. When a community is involved, as is usually the case, these difficulties are greatly multiplied, not only because of the many properties to be considered but because public utilities, some of which are almost indispensable as continuing functions, have a relation to public welfare entirely out of proportion to their physical value. Here are involved benefits, some of them intangible, to the community as a whole. Therefore, to make a first approach to the question of economic justification of a flood-control project by the method of an accurate determination of value of benefits will usually lead to long and sometimes unnecessary delay.

It is equally undesirable to advocate a policy that all flood-control projects are justifiable solely for the reason that they have *some* merit in preventing or diminishing flood damage. Unsupported general statements as to flood damage are often grossly exaggerated. Many cases are to be found where the cost of flood protection would greatly exceed any reasonable estimate of value of benefits. In some instances cost would be even more than ultimate value of the property to be protected.

Rating Projects by Approximate Methods

Obviously, some rational method of estimating benefits is desirable that will serve to indicate on the one hand those projects where benefits will probably exceed costs by a liberal margin, and on the other hand those where the cost will be considerably in excess of probable benefits. Wherever even roughly approximate estimates are available of damage due to a known flood, and where something is known as to probable frequencies of floods of given magnitudes, a basis is offered whereby certain flood-control projects may be selected as having ample economic justification, and others, by the same yardstick, may be rated as having little economic merit. Such procedure leaves a large middle class, where the economic status is uncertain, and where more exact methods must be used to ascertain the pertinent facts with greater accuracy. A final test, and one by which many justifiable projects will stand or fall, is the attitude of beneficiaries toward meeting their share of flood-control costs.

Benefits Wide-Spread

Flood-control benefits may often extend far beyond the limits of the community primarily affected. There may be a State interest, such as the protection of public roads, the stabilization of property values, protection of important industrial sections, or the promotion of public health and sanitation. Such benefits may even be interstate in character. Federal interest may lie in improved navigation facilities, harbor protection, protection of mails and interstate commerce, or of other situations of vital importance as military necessities, lowering of flood crests on the Mississippi river or one of its main tributaries, protection of public health from a National point of view. Allocation of such benefits calls for cooperation by the various interests concerned. In many States legal authority is now lacking for participation in such enterprises, even when the responsibility can be clearly shown. Where interstate responsibility is indicated, there is no practicable way to proceed under existing statutes. Federal participation is provided for under the National Industrial Recovery Act, which, however, is only an emergency measure.

Need of State and Federal Legislation

Clearly, there is need for uniform state laws to provide for flood-control districts within the states, and to permit interstate cooperation when that is desirable. Federal statutes are also needed, to authorize interstate compacts where such are required, and to provide permanently for Federal participation when that is proper.

Determination of Federal Interest

Because of the provision in the National Industrial Recovery Act that the Federal Government, during the life of the Act, may participate in the cost of flood-control projects, the question immediately is raised: As a basis for the extent of Federal participation, how may Federal interest be determined?

Under the National Industrial Recovery Act, the Federal Government may contribute to any worthy public-works project 30 percent of the cost of labor and materials. To that extent, therefore, for a limited time, a basis for Federal participation is indicated for projects that prove to be technically sound and economically feasible. It has been suggested that some such minimum participation might be made a feature of a permanent National policy.

It is an established policy that flood control of the lower Mississippi river and its backwater areas is a National affair. Therefore a project that can be shown definitely to diminish flood peaks on these areas, warrants additional Federal participation to the extent of the saving in Federal costs thus made possible in connection with requisite flood-control works on the lower Mississippi.

Navigation projects on certain inland rivers have been established by Federal funds. While some have served their purpose and others may not warrant further expenditures, there exist several navigation projects clearly important as parts of a national and permanent coordinated transportation system. Where a proposed flood control project will have the effect of minimizing flood damage to shipping on such worthy navigation projects, or, by flood control, or by low water control, will increase the length of the navigation season, such features may be a basis for Federal participation beyond the established minimum.

It is conceivable that a proposed flood control project may have the effect of promoting public health to an extent clearly beyond community or even State interest. Where such effect can be definitely established as of real value to the Nation, there is suggested an economic justification for still further Federal participation. In all these cases, the problem is to determine reasonable, though liberal, extent of Federal interest, without establishing a system of subsidies that may easily prove to be an inequitable drain on the Federal treasury.

Need of Adherence to a Rational Policy

Recent experience with applications for Federal funds to completely finance flood control projects of chief benefit only to local communities, indicates the necessity of adherence to a policy based on allocation of costs in proportion to benefits. While Federal participation may be liberal under such a policy, there is an obvious danger in yielding to local pressure to an extent that will involve the Government in obligations far beyond reasonable justification.

Local Interests Usually Should Furnish Land and Rights-of-Way

Costs of land, flowage rights, rights-of-way, local damages and similar items usually constitute a considerable portion of the total cost of a flood-control project. There are several reasons why local interests may well be required to pay at least that portion of the cost. Obviously, such negotiations can be carried out by local interests to much better advantage than by an outside agency like the Federal Government. Almost invariably the ultimate cost of such items would be less when handled by local agencies familiar with local values. By the same reasoning, more equitable individual settlements would be assured. Satisfaction of title, an expensive and laborious procedure where the Government is concerned, is greatly simplified when negotiations are concluded by and for local interests. In consideration of minimum *Federal* participation being established at a definite percentage of the construction cost, it is suggested that minimum *local* participation be established at the cost of necessary land, flowage rights, rights-of-way, and similar items. An additional reason, while operating under the provisions of the National Industrial Recovery Act, is that payment for such items has no direct effect on relief of employment.

A Policy for Federal Participation

With the foregoing as a background, supplemented by several months' experience in consideration of applications for Federal financing of specific flood control projects, the following is offered as a sound and liberal basic policy for determination of the extent of Federal participation.

1. In general Federal funds will be contributed to a flood-control project only where reasonable protection is afforded against floods of maximum height.

2. Federal funds as a rule will be contributed to a project, or to a principal unit of a project, only where the benefit from flood protection will justify the expense of such flood protection.

3. To projects of chief benefit only to local communities, Federal funds may be contributed to the extent of 30 percent of the cost of labor and materials.

(*a*) There must be a responsible and legally constituted local agency with which the Government may deal.

(*b*) Such local agency must guarantee the Government against any future claims for damages on account of the construction or operation of the project.

(*c*) Such local agency must provide all necessary land, flowage rights, rights-of-way, and similar items, as well as the remainder of the funds (in excess of the Federal contribution) required for completion of all essential construction work.

(*d*) Operation and maintenance costs shall be borne wholly by local interests.

4. To projects of substantial benefit to Federal interests as well as to local communities, Federal funds may be contributed in excess of 30 percent of the cost of labor and materials the amount of Federal contribution in excess of such 30 percent to be determined by the proportion of benefits definitely applicable to a recognized Federal interest.

(*a*) Federal funds so contributed shall be expended under the direction of a qualified Government agency.

(*b*) There must be a responsible and legally constituted local agency with which the Government may deal.

(*c*) Such local agency must guarantee the Government against any future claims for damages on account of the construction or operation of the project.

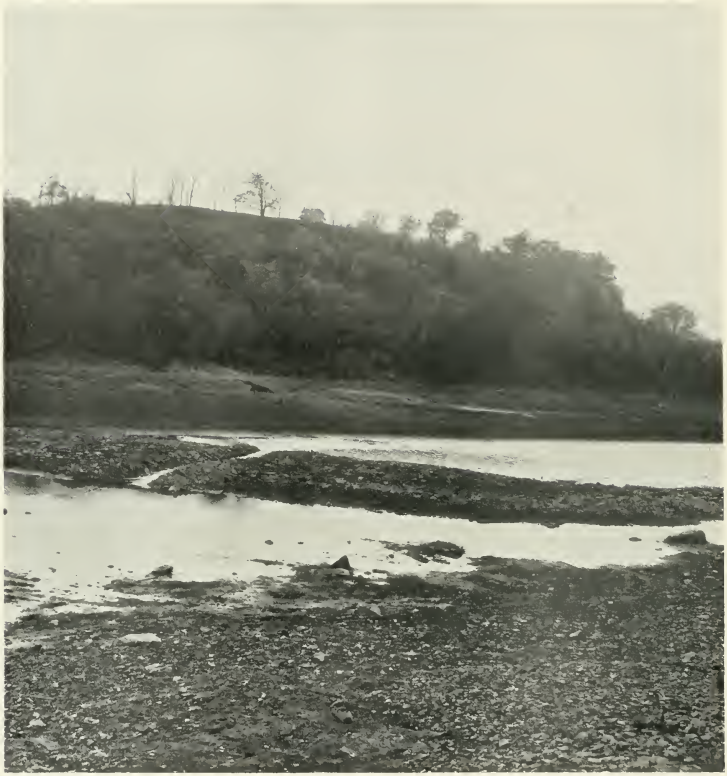
(*d*) Such local agency must provide all necessary land, flowage rights, rights-of-way, and the like, as well as the remainder of the funds (in excess of the Federal contribution) required for completion of all essential construction work.

(*e*) Operation and maintenance costs shall be borne wholly or in part by local interests as may be determined in each case.

5. To projects of chief benefit only to Federal interests, where benefits to local interests are largely incidental, Federal funds may be contributed up to 100 percent of the construction cost, provided, however, that local interests may be required to furnish all or a part of the necessary land, flowage rights, rights-of-way, etc., as may be determined in each case.

The foregoing is suggested as a basic policy. It is recognized that emergencies, local or national in character, may justify more or less departure from any general policy that may be adopted; that changing conditions, in this as in many other fields, may warrant or dictate a modification in policy; that a new concept of public responsibility for social betterment may have its influence on policies established in the light of present viewpoints. Granting the possibility of all such influences, it is believed that this suggested basic policy is sound, well balanced, liberal, and sufficiently flexible to meet the requirements of new conditions as they arise.

A NATIONAL POLICY FOR LOW WATER CONTROL



Monongahela River near Morgantown, W.Va. This view is in the canalized reach during the severe drought of October 1930.

A NATIONAL POLICY FOR LOW-WATER CONTROL

Low-water flow in a stream occurs during periods of infrequent or light rainfall, when surface run-off from the drainage area has been practically exhausted. At such times the flow is limited mainly to that supplied by ground water seepage. Most streams, even during years of normal rainfall, have periods of low-water flow continuing for several weeks and sometimes for several months. In the semi-arid and arid sections of the country these low-water periods are of longer duration, and it is not uncommon, particularly in the arid sections, for the surface flow of streams to disappear entirely for months at a time. During years of subnormal rainfall these conditions are correspondingly intensified.

When the low-water flow of a stream diminishes to the point where it becomes a series of stagnant or semistagnant pools, the need for low-water control is apparent. The obvious remedy of connecting up such pools with a ditch, forming a continuous-flow channel, is perhaps one of the simplest examples of low-water control. This, however, while affording some relief, falls far short of accomplishing the most desirable results, though it accomplishes something in maintaining a live stream.

Disposal of sewage and effluents from sewage-treatment plants and from industrial wastes often requires more stream flow than is available during low-water periods; mine drainage and certain industrial wastes produce an acidity that calls for dilution; fish life requires a supply of free oxygen; water supply is often seriously deficient during low-water periods; recreation activities may be seriously curtailed. Questions of public health are often involved. It is clear, therefore, from these few outstanding examples that failure to maintain a necessary minimum flow often leads to consequences more serious than would be expected at first thought. It is the low-flow streams that are most seriously affected by a given amount of pollution, and the lower the flow the more is such pollution intensified.

Methods of Control

To accomplish adequate low-water control, storage of flood waters is the first plan that suggests itself. Storage for the sole purpose of low-water control may not often be justified, but fortunately the necessary supply may be available as incidental to power development, irrigation, navigation, water supply, or even flood control. The latter is not as easy to coordinate as some of the others, because one of the basic principles of flood-control storage is that flood waters caught in a reservoir should be released as soon as possible to provide storage space for another flood, while low-water control dictates a certain minimum flow in the stream over a long period of time. But sometimes even these apparently conflicting conditions may be coordinated.

Benefits and Allocations

Whether low-water control is accomplished by works especially designed for that purpose alone, or whether it is a part of a multiple purpose project, the value should be estimated with reasonable allowance for such items as health protection, preservation of fish life, aesthetic considerations, the actual values of which are difficult to determine. Benefits to water supply, waste disposal, water power, navigation, etc., usually may be evaluated with a closer approach to accuracy.

Having determined the economic feasibility of the low-water control features of a project, allocation of benefits should be made to community, state, or Federal interests as they may appear. The policy that may be adopted for flood control projects may well be used as a basis for a low-water control project insofar as practicable.

Need of Pollution Control

Consideration of this subject inevitably brings up the question as to how far communities, or private industries, should be compelled to go in treatment of sewage or waste before being permitted to discharge them into flowing streams. Many factors are involved, some of them varying almost daily for a given stream. Manifestly, a reasonable degree of control is of vital public interest, while too restrictive measures might easily be carried to the point of impracticability. Nevertheless, low-water control can never be worked out on a consistent basis without some uniform standards for pollution control. Public-health organizations, cooperating with industrial interests, should work out a sound basis for such standards.

Need of State and Federal Regulation

Federal and uniform state regulations are needed, and are fundamental to a proper consideration of any general policy for low-water control. Federal participation may well be withheld from low-water control projects where pollution is a factor, until after satisfactory pollution control is assured.

A National Policy for Low-Water Control

Policy

For such low-water control projects as may be found to be technically and economically sound, the extent of Federal participation might be determined by the following policy.

1. In general, Federal funds will be contributed to a project where pollution is or may be an important factor, only after satisfactory pollution control is assured.

2. Federal funds as a rule will be contributed to a project, or to a principal unit of a project, only where the benefits from low-water control will justify the expense of such control.

3. Projects may be classified, as in the case of flood-control projects, into three groups.

   a. Projects of chief benefit only to local communities.
   b. Projects of substantial benefit both to Federal interests and to local communities.
   c. Projects of chief benefit only to Federal interests.

The policy suggested for Federal participation in flood-control projects in each of these groups (see "A National Flood Control Policy") is offered as applicable also to low-water-control projects.

A NATIONAL INLAND WATERWAY POLICY

The Waterway Scene

For centuries mankind has used inland waterways for transportation purposes. In the exploration of the New World continents developments generally followed river routes. Up to seventy-five years ago the bulk of the commerce of the United States was water borne. Even today we have some water routes carrying heavy tonnages on an economic basis. The national investment in waterways runs into the billions. While such facts afford wholly inadequate guides for future national policy as to river improvements, they do suggest racial and national instincts and institutions to be dealt with both considerately and rationally.

In the face of this need for poise and deliberation the discovery is easily made that in the discussion of general policy, or its application to individual projects, advocates rather than impartial judges, partisans rather than disinterested technicians, have the public ear. Back of the appeals of the proponents of river navigation projects is seen all too frequently only a drive for lower railroad rates and this usually with no special regard either to the economics or equities involved. On the other hand, it is equally clear that sometimes the opponents of such projects are actuated, consciously or unconsciously, by a desire to protect a vested interest in some competing mode of transport.

There is one universally held theory and that is that all methods of transportation should be "coordinated." However, when one gets down to particulars this coordination too frequently is apt to mean some adjustment as between trucks, railroads, and waterways held to be advantageous by the one making the suggestion.

Adequate Transportation Basic

The maintenance of an effective comprehensive transportation system is possibly the most fundamental, immediate problem that we have to face. A nation with our territorial extent, population, culture, and vital dependence of one section upon another, is unique. It has been made possible only by an elaborate and adequately supported railroad system. Therefore any move, however desirable it may be in itself, which unduly infringes upon the serviceability of railroads, is to be deprecated.

In justification for those who oppose the extension of our waterway system it must be remembered that we do frequently keep on doing things just because we have done them in the past. On the other hand back of the drive for waterways there are frequently vested interests seeking special privileges.

There are technical arguments against river developments entirely disassociated from cost considerations:

(1) the disadvantageous courses of many rivers (circuitous or athwart the normal lines of traffic movement);

(2) the inflexibility of water transport and the associated fact that comparatively little freight can move wholly by water from a point of origin to a point of consumption, defects that may entail relatively heavy costs for reshipment;

(3) the impracticability of fixing wharfs, docks, and warehouses on the banks of most inland rivers because of the great variation in stream levels; and

(4) the closure of northern waterways in winter, with resulting seasonal suspension of traffic.

But in recognizing every plausible objection to be cited against extensions to our system of inland waterways we should not lose sight of some further pertinent facts:

(1) the privately owned railroads have been consistently opposed to virtually all waterway transportation without discriminating appraisal, the control of which they could not secure;

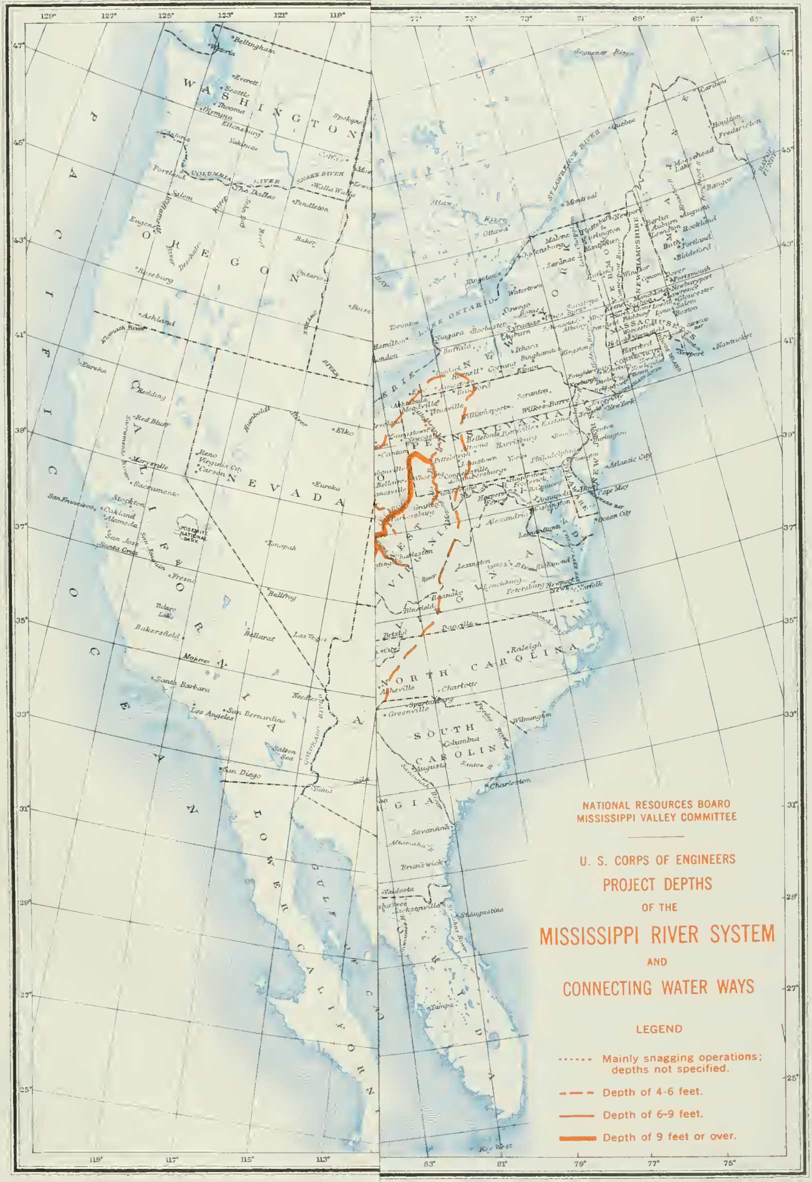
(2) essential and proper rate revisions on railroads have in certain instances come about only through waterway improvement;

(3) there are inland waterways in operation in our country, the economic justification of which is generally admitted; and

(4) Government—Federal, State, and local—already has a large investment in waterways which it probably would be quite impossible, if not unwise, to ignore.

Public and Private Rights and Obligations

If the Government is to retain the confidence of our people it must be reasonably careful in all actions which affect private interests so as to safeguard the real equities involved. But we must here as elsewhere have in mind that the public and the private interest are of wholly different orders. Government frequently cannot effect the largest good of the greatest number without infringing private rights. The Constitution affords protection or compensation for a genuinely injured party. Therefore, it may be a feeble argument against a waterway to say that it is going to injure a privately



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PROJECT DEPTHS

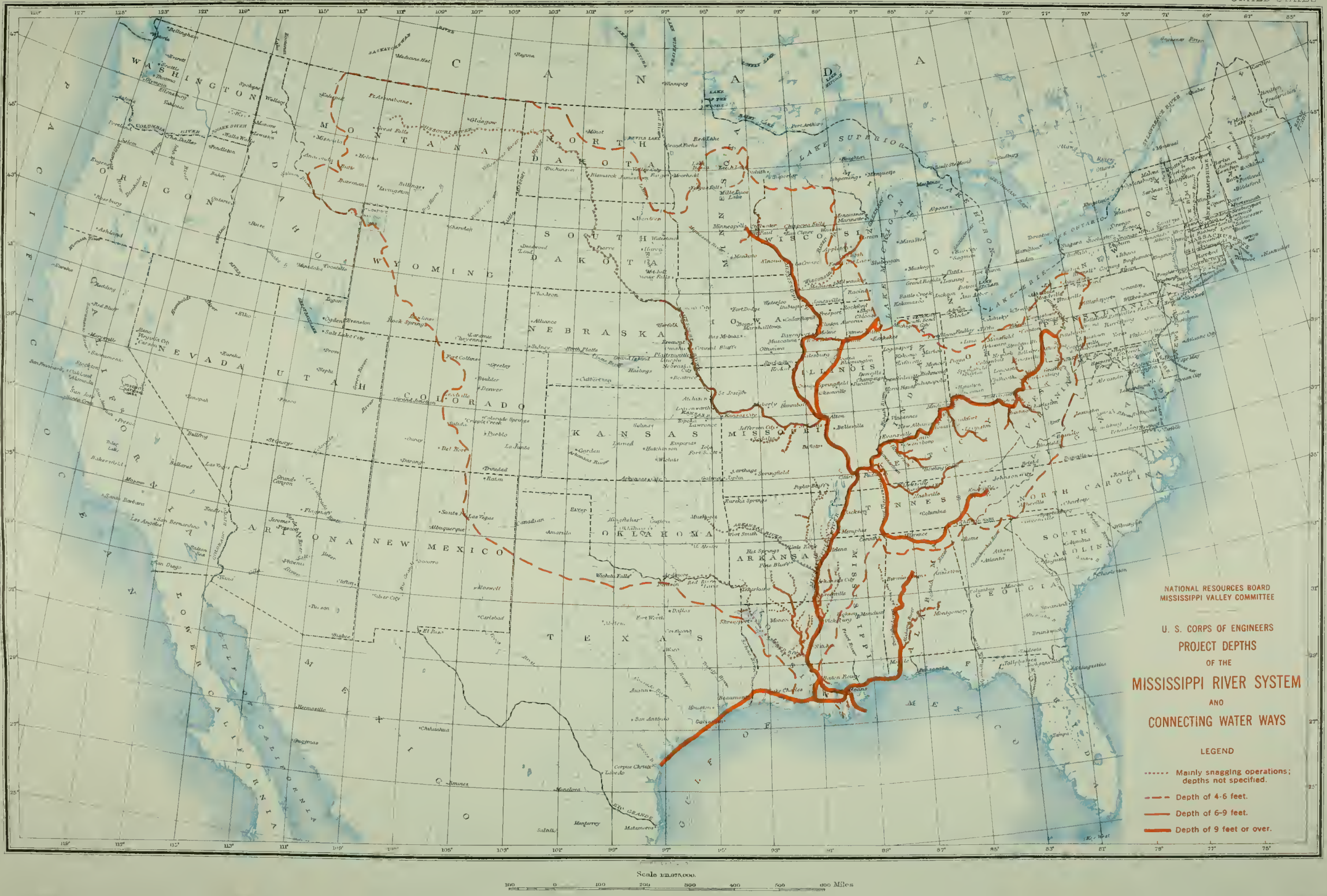
OF THE

MISSISSIPPI RIVER SYSTEM

AND

CONNECTING WATER WAYS

LEGEND



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PROJECT DEPTHS OF THE MISSISSIPPI RIVER SYSTEM AND CONNECTING WATER WAYS

owned railway or even the railway system as a whole. A railroad is no more free from the outcome of technological evolution or of new social institutions, than is the corner grocery store. Under free institutions there can be no absolute and final restriction on the things Government can do if the people desire to do them. Hence waterway policy even if it perpetuates a toll-free system may be sound from the standpoint of institutional democracy, even if it be costly from the standpoint of the budget makers.

Every variety of transportation facility—rivers, railroads, highways, and airways—has received subsidy at one time or another. The wisdom of a subsidy must be judged by the situation at the time it is granted. When certain transcontinental railroads were subsidized through land grants the country was in dire need of these cross-country routes to overcome delays and inconveniences of the covered wagon and the mule train. Transportation subsidies in the past—in theory at least—have been considered warranted only where there has been an urgent need for the expansion of transportation facilities not readily procurable through private initiative. Certainly the warrant for transportation subsidies in a period of vast and rapid expansion is much more apparent than at present when we are having difficulty in holding and consolidating our economic position.

In reaching conclusions that are to hold through a considerable term of years, as is inherent in the Mississippi Valley Committee assignment, it is not feasible to build too exclusively on what is, or, especially, on what has been. One should have in mind that in making assumptions as to what the transportation system of 40 to 50 years hence should be, all the mistakes and lack of efficiency so much a part of the present can be largely ignored, because of the good offices of amortization and obsolescence. To plan 50 years ahead is, as it were, to plan with a clean slate. Such considerations cannot wholly control our thinking and planning, but they do allow some measure of freedom from the trammels of what is.

Transportation modes and transportation routes are peculiarly open to obsolescence. But both the very large investments usually involved and the far-reaching relations of the public and private interests that may be affected by change, frequently warrant retaining facilities long after their profitableness from a strictly accounting standpoint has disappeared. This logic applies to waterways and railroads alike, once they are established, even though later developments raise a question as to the wisdom of the original investment.

Had we no noble streams, such as the Columbia, the Delaware, the Hudson, and the Mississippi, tying our interior by obvious transportation routes with the open ocean, and no great inland seas such as the Great Lakes and, particularly, if we had never gone in for inland waterways, our problem would be different. But we are in it, and in it deep, and probably to stay, if only for the reason that development or regulation of a given river may be desirable from one or more standpoints other than navigation. Irrigation, flood control, low-water control, and power development, one or all, may incidentally improve the navigability of a river. So our task is to take the situation as it is—not as any one of us would construct it anew—and plot a reasonably logical future with the present as its base.

Outlays for Rivers and Harbors

The policy of improving rivers and harbors in the United States under Federal direction and with Federal funds was begun more than a hundred years ago. The first appropriation for the improvement of the Ohio (first member of the Mississippi System to receive attention) was made in 1824. The total of the appropriations for rivers and harbors from the inception of the work to June 30, 1932, including flood control, is $1,941,779,999.

TABLE I.—*Comparison of total amounts appropriated by Congress by specified dates for rivers and harbors*

To June 30	Aggregate of appropriations	Percent of total appropriated to June 30, 1932
1882	[1] $111, 299, 465	6
1906	[2] 515, 427, 432	26
1910	[3] 660, 604, 210	34
1915	[3] 853, 737, 951	44
1920	[3] 1, 041, 805, 547	54
1925	[3] 1, 311, 597, 443	67
1932	[3] 1, 941, 779, 999	100

[1] River and Harbor Improvements 1789–1883, House Doc. No. 64, 48th Congress, 1st session.

[2] Transportation by Water, Bureau of the Census, 1906.

[3] Annual Reports, Chief of Engineers, U. S. Army, for years indicated. The last three items include flood control.

The amounts stated for 1882 and 1906 are not on the same basis as the others, but the discrepancies are not sufficient to be significant. These data indicate that during the period 1920–1932 almost as much money was appropriated for Rivers and Harbors as during the hundred years preceding 1920.

Some part of the expenditures for flood control on the Mississippi River is properly chargeable to navigation, but the amount thereof is difficult of determination, for some construction serves both purposes. As a matter of fact, of the $325,000,000 authorized by the Act of May 15, 1928, for flood control on the Lower Mississippi, $100,000,000 was charged against navigation.

The total expenditures of United States funds up to June 30, 1932, when adjusted in the manner heretofore indicated, to exclude amounts not attributable directly to navigation of the rivers and harbors of continental United States, is reduced to $1,534,862,753. This amount includes the value of plant, materials, etc., on hand, accounts receivable and accounts payable. The cost of new work is $1,062,217,931, and maintenance $435,812,044 subdivided as follows:

	Cost of new work	Cost of maintenance
Seacoast harbors and channels	$444, 684, 556	$163, 553, 714
Lake harbors and channels	157, 190, 628	41, 126, 585
Mississippi River System	377, 816, 695	61, 274, 077
Intracoastal canals and other waterways	82, 536, 052	27, 817, 860
Operation and care of canals		116, 858, 340
Miscellaneous		25, 181, 467
Total	1, 062, 227, 931	435, 812, 043

The above totals include the cost of new work and of maintenance for projects which have been abandoned or are no longer active, amounts which have been expended on active projects for improvements which have been destroyed, abandoned, or replaced, and the costs of other construction, such as required for protection, flowage rights, and bridges carrying railroads and highways across the channels being improved. In most cases, of course, the expenditures for highway and railroad bridges necessitated by river improvements were not made by the Federal Government. They were, nevertheless, an essential part of the social cost of such projects.

The streams of the United States under improvement or which have been improved are here summarized.[1]

Streams tributary to—	Number of streams	Navigable mileage
Atlantic Ocean	214	5, 572
Gulf of Mexico (exclusive of Mississippi River)	67	4, 621
Gulf of Mexico from Mississippi River and Branches	43	12, 798
Pacific Ocean	40	1, 663
Great Lakes	10	462
All other	13	2, 290
Total	387	27, 406

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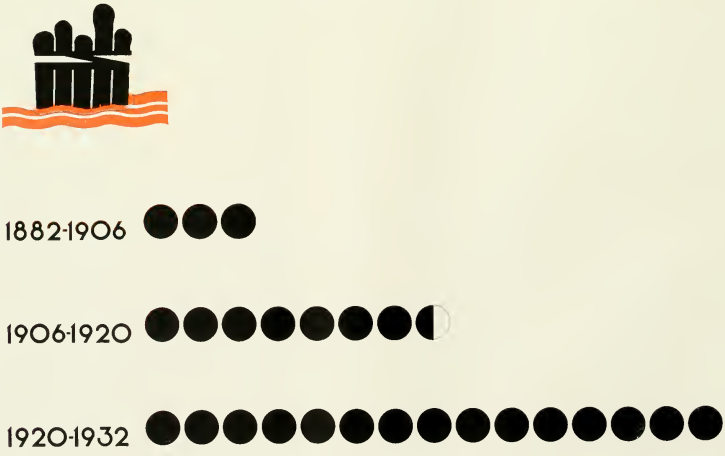
[1] Data from Statistical Bureau, Board of Engineers for Rivers and Harbors, U.S. Army.

AVERAGE YEARLY APPROPRIATION FOR RIVERS & HARBORS
1882 TO 1932



EACH COMPLETE DISC = $5,000,000

Summarized according to controlling depth at low water, the mileages are approximately as follows:[2]

	Length (miles)	Percent distribution
Under 4 feet	11,377	41.6
4 feet and under 6 feet	5,891	21.5
6 feet and under 9 feet	4,784	17.4
9 feet and under 12 feet	3,755	13.7
12 feet and over	1,599	5.8
Total	27,406	100.0

Included in the mileage having a controlling depth of less than 4 feet are 1,895 miles of the Missouri River above Kansas City, and the upper reaches of various other rivers.

Some portions of through waterways may have large tonnages, while other portions may have extremely low tonnages. A given river which may have been canalized to carry parts of these tonnages may now be maintained at a relatively high cost, and in itself may not have been worth the price that was paid for its development. However, if the particular stream has become a traffic feeder for a main route, such as the Ohio or the Mississippi, its abandonment is open to serious question. This is especially true if the cost deficit which the stream in question sets up is fully reflected in the picture of costs for the system as a whole. The reluctance to change transportation systems or modes, however, becomes highly objectionable when carried too far.

Perhaps the rapid transition to pipe lines for carrying oil may be cited as a well advised shift. Pipe lines certainly represent a direct improvement in transportation. This improvement came about because of industry's ever watchful demand for lower cost transportation methods, the appearance of new technical facilities and economic conditions, and the power of a great industry to make the necessary investment.

There are 93,000 miles of pipe lines in the United States. They handle not less than 75 million tons of crude oil a year, transporting it an average distance of over 500 miles, and produce revenue for the owners in the order of about 200 million dollars per annum. This sum of income is about 8 percent of the total freight revenues of the railroads of the country and it represents not less than 35 billion ton-miles of revenue freight traffic.

Millions of barrels of oil are carried by ships and barges along the coasts and in the rivers of the United States. Tremendous fleets of tank wagons redistribute the various forms of petroleum products. The very existence of this combination of pipe lines, tank steamers, barges and tank wagons bears evidence to a degree of flexibility and accessibility, and a lowering of cost in the transportation of petroleum products, which the railroads were unable to meet. As a result petroleum products are cheaper to the consumer and the social income is increased.

Waterways and Railways Complementary

Similarly we have developed inland water routes which carry millions of tons of products. The water routes were first developed because of the movement of the early pioneers into the vast inland areas. Then the railroads came, and proved through their greater flexibility and ability to tap regions not close to the rivers, a great transportation asset. Both the railroads and the waterways serve at varying costs the transportation needs of the country and in each area sometimes at rates largely based on the competition. Because the water routes are free to many private and common carriers, and have been developed over a long period of years at the expense of the national and state Governments, it is contrary to sound reasoning to think of abandoning them simply in order that this additional freight may be carried on the railroads.

> These natural highways, the waterways, can never be monopolized by any corporation. They belong to all the people and it is in the power of no one to take them away.—THEODORE ROOSEVELT.

Any expansion in transportation facilities to meet an eventual increase in traffic should be along the lines of the most economical investment and development. To permit the vested interest in the railroads to monopolize the entire increase at the expense of a large section of the country desiring to make use of a genuinely cheaper mode of transportation to market, for many of its bulky and low-value products, or to the place of further manufacture, would not appear to be good national economics.

Importance of Coordination

In recent years a tremendous highway development has taken place over a large portion of our country. The automobile brought this about. Automobile trucks operated by enterprising business men have grown tremendously in number, simply to serve better the transportation necessities of our nation. The auto truck is here to stay, to serve various classes of work and carry various classes of commodities.

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[2] Adapted from data in "An Economic Survey of Inland Waterway Transportation", Bureau of Railway Economics, 1930.

But so are the railroads here to stay. They will probably continue to be, for an indefinite period, the backbone of the transportation facilities of the country. The pipe line systems are here to stay, for a very long period to serve various and particular functions, largely in the field of petroleum and its products. Similarly, the waterways are here and in some localities are of such importance that additional money for maintaining and for increasing their capacity can be well spent. This does not mean that every possible waterway in this country should be developed. It is quite unlikely that many of the routes currently considered as possibilities will ever be developed.

But it should be stressed that a definite plan for transportation as a whole, incorporating all of these various methods, is needed. The objective is a definite plan to continue every variety of facility, and to expand each when necessary, so as to provide a system which will give us the benefits of the lowest cost transportation. The great opportunity lies in a coordinated use of waterways, railroads, pipe lines, and auto trucks so as to effect the maximum of flexibility and accessibility at the lowest long-run cost. Planned economy ought to move in no other way.

Necessity for Cost Data

Irrespective of the disposition of questions of policy, reasonably exact cost data should be available on all proposed waterway projects so that public opinion can be informed before binding commitments are made. Provision, therefore, should be made for estimating, costing, and accounting of a type which will give the public, the fullest and most dependable grounds on which to base action. It has now become obvious that all governmental estimating and accounting must be kept abreast of the best current standards involving as they do adequate checks between estimated costs and those actually realized.

Both accounting and cost finding techniques have now progressed to the point where they constitute fully developed and independent arts, quickly appreciated and utilized by industry. It will constitute a real step forward when government learns to avail itself of them.

A system of accounting is also required through which the capital investment, as well as maintenance and operating costs, on any given going navigation project can be currently determined. In figuring present investment, it should be recognized that outlays previous to a certain date have been amortized by time if not through accounting procedures.

Only those outlays reasonably chargeable to navigation should be included in these navigation costs. Where a river project is built for joint or multiple use, each of the purposes—recreation, power, flood control, etc.—should have allocated to it the proper percentage of the total outlay.

The nation undoubtedly needs more definite and disinterested data to show the relative costs, taking in *all* factors, of transporting commodities by inland waterways in comparison to other media of transport. Factual data are needed on this subject to establish justification or nonjustification for either the building or continuation of any waterway program whether it be extensive or limited. The same type of cost data will be required for other means of transportation if the absolutely necessary comparisons are to be made.

Any national navigation policy should comprehend a careful and comprehensive study of the economic justification of proposed new improvements in inland waterways. It is believed that this phase of the subject has in some instances in the past been too lightly considered—if considered at all. Economic justification should be definitely established early in the study of any proposed river or canal improvement.

Rates Based on Costs

In the long run, and as a general policy, all transportation rates should be based on the whole cost of the service rendered. But this policy today is not feasible as to rail rates; first, because dependable data as to rail costs are not now available and, second, because if they were available the social interest in many instances would not be served by a too rigorous application of rates based on costs. Where communities and industries have been built up through what was, or has become, preferential treatment as judged by cost of service, moderation must frequently be used in applying rates based wholly on costs. Therefore cost as the single basis for rates cannot be too rigorously enforced in other parts of the transportation field.

If one could assume that rail rates were based on cost plus a reasonable profit, the lowering of a given rate to meet water competition would involve raising rates elsewhere to meet the loss. In fact this is what happened during the period of waterway development in parts of the South drained by the Mississippi and its branches. Just what advantages, if any, should be accorded to those living near a river as contrasted with those in the back country is an involved question.

It is not regarded as necessary, nor indeed practicable, to use waterway projects—either actual or potential—for the general regulation of railroad rates. Such rates should be regulated to the extent necessary to guard the public interests with due regard to the existence of competing modes of transportation whether the latter are similarly regulated or not.

Nor is it necessary to deprive an existing railroad of the freight which it may be able and willing to transport, with at least an operating profit, in competition with a waterway, merely to swell the traffic on the latter. But the economic value of the waterway cannot always be determined solely upon the basis of the tonnage actually carried; due credit should be given for the reduction in transportation rates whether or not actual transport remains with the railroad.

Until we know more than we do today about the actual costs of waterway improvements in terms of the burden to be carried, actual and potential, it is difficult to suggest a policy as to the extent and nature of the charges for the use of navigation facilities provided at Government expense. Generally speaking, reasonable charges should be levied on new projects. This should not be so interpreted as to preclude promotional rates during the development period.

Where making such charges would bring about the disuse of facilities already in existence, and especially where the Government is under no material expense for maintenance and operation, it would be unwise to levy charges on such existing projects. The policy should be generally to charge something where special services or special facilities are provided.

In further consideration of this matter we should know that a considerable body of the well informed feel that a charge for the use of inland waterways would be, under the present rate set-up and relations with the railroads, unduly restrictive and tend to divert traffic from the waterways. The railroads with their heavy overheads are in a strong position to cut rail rates more or less indefinitely to capture or hold increments of traffic which otherwise might be water borne.

The policy of the Government should look toward the establishment of a more scientific basis for rate making, based upon cost and kind of service. This is not only true of waterways, but of all other media of transportation. A revamping of the entire rate structure of the country would appear to be essential before a properly coordinated system of transportation can be effected.

Unification of Waterways

Given an inland waterways system, the better unified it is, other things being equal, the better. A unified system, if any, must necessarily be the objective, and not a more or less useless collection of disconnected segments of varying widths and depths. Public policy has been too vacillating, and lacking in consistent and energetic attack. As a result public expenditures for waterways have been proportionately ineffective. Again if we are to have improved waterways they should be used. And the techniques by which they are to be put to work and kept active are as important as their construction.

In order to obtain the best results, it is believed that a greater degree of local cooperation should be required if the Federal Government is to participate in the development of waterways on a large scale. If a project is worthy of recognition by the Federal Government, it is worthy of some local participation. River improvements, in most instances, confer an especial benefit upon portions of the country most nearly affected. There is always danger of insistent pressure upon the Federal Government for the expenditures of money upon projects which have not been maturely considered, and which, if part of the burden were chargeable to the localities in which they are advocated, might not be presented to the Congress.

Where waterways have been begun, they should be completed, generally speaking, unless it has become clear that they are lacking in economic or social justification. Where the estimated expense is considerable, and especially where the economic or social justification is responsibly questioned, procedure might well be as in the case of new projects.

Advantages of a Waterways Commission

It is strongly held by some interested in waterway transportation that it would not be wise policy to place waterways under the jurisdiction of the I.C.C.—a body which up to the present time has been largely concerned with railroads, of which the problems are becoming progressively more complicated and exacting.

Perhaps a master move toward the eventual coordination of railroads, waterways, and all other modes of transport would be the setting up of a commission to regulate water rates and cooperate with the I.C.C. in setting joint rail and water rates. Through such an agency the whole waterway situation could be studied.

Thus there would be promulgated an outlook and practices as to water-borne traffic which, through general discussion, can ultimately gain some measure of technical and public approval. After public opinion has been given a chance through the broad functioning of such an agency to arrive at some basic conclusions, the consolidation of all Federal regulating agencies might easily become the next logical step.

Following the appointment of such a waterways commission, one of the first duties would be the determination of the reasons why so small a percentage of the present commerce of the nation is now moving on our inland waterways, why the barge lines now operating on our costly waterway system cannot develop and, especially, hold their fair proportion of freight traffic, and why the possibilities of such streams as the Hudson go practically unused. Also, it would be enlightening to know why it is that in countries where railroads are owned wholly or in part by the state (France, Germany, Belgium, etc.), and where impairment of railroad values by water navigation would naturally be guarded against, there have been consistent policies of development of water navigation, whereas in the countries in which railroads are privately owned there has been no such national waterways policy.

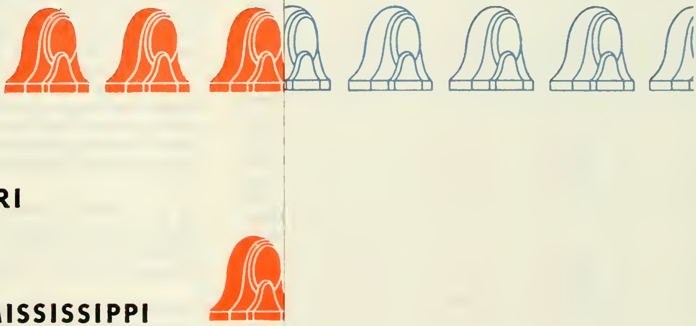
It is tragic that in a matter so obviously important as is inland waterway transportation such data as are available should receive so little common recognition. Until this factual situation is generally understood, public opinion will remain grounded largely on guesswork and the whims of the moment.

POWER—A COORDINATING FACTOR
IN
RIVER DEVELOPMENT

(The Map showing the distribution of the fields of operation of leading electric power groups was printed by courtesy of the copyright owners only in a few copies of this report circulated for official purposes. The map could not be included in the generally distributed copies of this report.)

Installed Ca Installation

INSTALLED: STEAM



BASINS

OHIO

MISSOURI

UPPER MISSISSIPPI

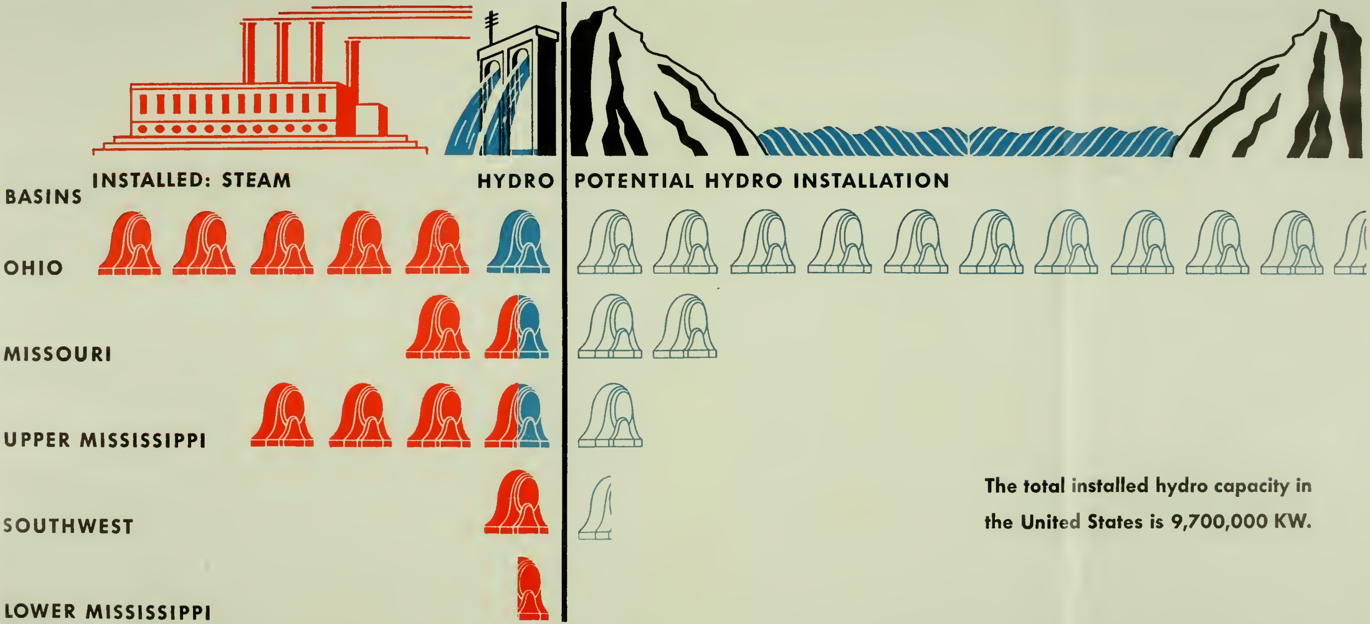
SOUTHWEST

LOWER MISSISSIPPI

installed hydro capacity in
ed States is 9,700,000 KW.

EACH DYNAMO REPRESENTS

Installed Capacity and Potential Hydro Installation



The total installed hydro capacity in the United States is 9,700,000 KW.

EACH DYNAMO REPRESENTS A CAPACITY OF ONE MILLION KW.

POWER—A COORDINATING FACTOR IN RIVER DEVELOPMENT

Power, flood control, low-water control, navigation, irrigation, a wide-spread development of rural electrification, and an extensive national reserve against unemployment, appear inextricably bound up in the possibilities of the undeveloped waters of the Mississippi Valley. Building a dam for flood control alone may not be economically feasible, but, when given multiple purposes such as power, recreation, and navigation along with flood control, the economic status of such a dam may show a decided improvement. So it appears to be with the development of the waters of the Mississippi Drainage Area as a whole. Approached from any one standpoint, whether flood control or navigation or power, their full control and use for the highest social purpose may seem remote. Likewise when approached from a limited regional standpoint the solution of any one problem may appear impracticable. But if we can utilize these undeveloped resources on a Valley-wide and multiple-purpose basis the goal of their maximum and best use seems within reach. A most promising key appears to lie in the unification of the national electricity supply.

Power Resources

The total water-power possibilities of the Mississippi Valley, together with the installed capacity of existing plants, both hydro and fuel generation, are given in the accompanying graph.

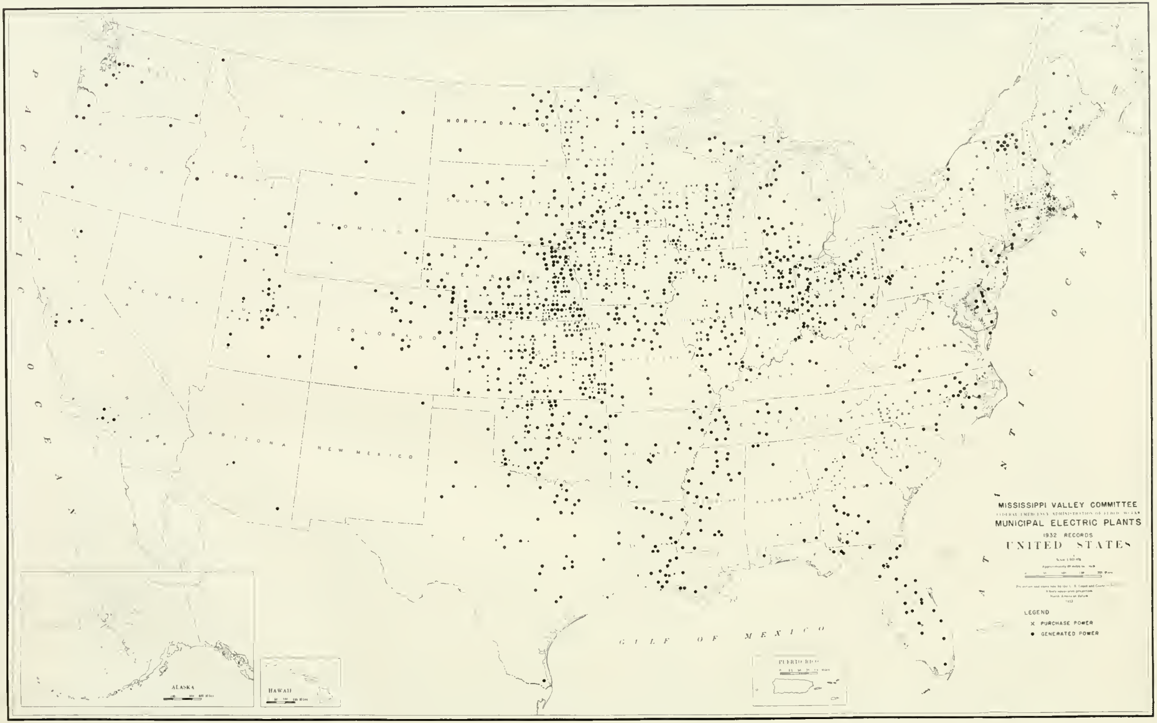
An analysis of the data on which this chart is based shows that while the water power possibilities of the Mississippi River and its tributary streams approximate 16,000,000 kw., not more than 2,000,000 kw. have been developed. It thus appears that around seven-eighths of the Valley's water-power resources are yet undeveloped.

The low-cost and medium-cost power sites possible of development are estimated to total 11,836,400 kw., a close approximation to the total present installation of all kinds, namely, 13,065,000 kw. Even though the Government had title to a water-power project, the time and economy of its development would be influenced by the prevailing cost of power as produced by coal, gas, or oil—especially when the project is one disassociated from other objectives such as navigation or flood control. The low operating cost of hydro projects and the social advantage of utilizing an inexhaustible resource, and one wasted or lost if not used also have a bearing.

Out of the 11,836,400 kw. of low- and medium-cost feasible power installations undeveloped, 9,151,500 kw., or 78 percent, is in the Ohio subbasin and therefore generally in the region of the largest populations and most important manufacturing centers. It does not follow, however, that any given dam in the Ohio Drainage Area is in such proximity to a center capable of utilizing its possibilities of power production as to make its development at present economically feasible. Such power sites have, as a rule, already been developed. However, even if relatively remote from consumption centers, and therefore uneconomical to develop, most power sites could be tied into a region-wide system. Once this objective is set, many site developments become feasible particularly if and when regional transmission networks are interconnected over wide areas.

In the case of dams built primarily for navigation or for flood control, or for these purposes combined, the power generated is frequently a byproduct. The percentage of constant or prime power in such installations is quite frequently too low to make power development attractive when such projects are considered as individual units rather than as contributing agencies in a far-flung interconnected system. The diversification made possible by wide interconnections changes into firm power what would be secondary or "dump" power when not so interconnected. Some dams built exclusively for flood control can be used at certain seasons wholly for power, for floods never occur in all areas at the same time, and, in some regions, indications of flood conditions—or their absence—may appear well before the flood seasons. While the electrical industry has had an abundance of experience in operating hydro plants, in harmony with other hydro plants and with steam plants, the full technique of playing impounded waters as parts of a unified system remains to be further developed.

There is nothing novel in the conception of a completely unified system for generation and transmission of electricity. Over wide areas such unification exists. It should not be difficult to reconcile the public and private interests involved in including in such a system power from dams which are built primarily for the proper use and control of the nation's water resources. The legal and operating problems appear relatively trivial in contrast to the great social purposes to be accomplished.


MISSISSIPPI VALLEY COMMITTEE
FEDERAL EMERGENCY ADMINISTRATION OF PUBLIC WORKS
MUNICIPAL ELECTRIC PLANTS
1932 RECORDS
UNITED STATES
LEGEND
X PURCHASE POWER
● GENERATED POWER
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
NORTH DAKOTA
SOUTH DAKOTA
MONTANA
WYOMING
COLORADO
NEW MEXICO
ARIZONA
NEVADA
UTAH
IDAHO
OREGON
OKLAHOMA
KANSAS
NEBRASKA
ALABAMA
TENNESSEE
MISSOURI
WISCONSIN
ALASKA
HAWAII
PUERTO RICO

The result will eventually be a single ocean of energy embracing every power source whether publicly or privately owned and all for the use of the mighty civilization developing in the Mississippi basin.

Effect of Present Status on Use

The need for coordination and unification is emphasized by an examination of the two accompanying maps—one showing the fields of operation of the leading private electric-power groups and the other the plants owned and operated by municipalities. The first has been called a "crazy patchwork" of operating areas, but the second is likewise a mass of independent, unrelated, and frequently uneconomic generating units. All concerned suffer from isolation.

In an area comprising central and northern Illinois, eastern Missouri, northern Indiana, southern Michigan, and a section of Wisconsin—in which are located the cities of St. Louis, Chicago, Milwaukee, and Detroit—the installed generating capacity is 4,585,000 kw., of which only 66 percent was in use as measured by the maximum peak load. Using the British estimate of an excess capacity of 15 percent as necessary to sound operation if all generating plants were feeding into a comprehensive transmission system, there would still remain 1,086,000 kw. of installed equipment not in use. Studies of comparable areas in Pennsylvania, New York, and New Jersey show excess generating capacity over maximum peaks ranging from 30 to 37 percent.

However, measured against the greatly increased demand which the policy outlined in this report would certainly make possible even the largest of these power centers are not "over built." Nor will the output of existing systems, public and private, augmented by hydroelectric power generated by the Government as a part of its flood control-navigation-power policy, meet long-range requirements. The supply must still be supplemented by fuel stations, and happily the Mississippi Basin is rich in coal, lignite, gas, and oil. The wide range of higher uses to which the Nation's oil supply can be put should, however, discourage its use for central-station-power supply.

The power picture of the Mississippi region which confronts us, therefore, is that of certain overbuilt areas unable to sell the power which their installed capacity enables them to generate; of other areas, especially rural regions, which enjoy no electrical service at all; of general domestic and municipal under consumption; and of a large number of municipal plants generating their own current which could be more economically served from the common pool.

To provided in consierable measure the leadership for the accomplishment of these momentous economic and cultural gains in the years just ahead is a task of Government. But any such planning must provide for an orderly and gradual development in which both public and private interests are fully considered. In the new order here suggested, which can necessarily achieve its purpose only through the progressive building of group and regional and interregional transmission networks, all interconnected, existing generating and transmission systems, public and private, will not only be needed but will find their advantage in cooperating in the larger unified scheme.

The private companies would gain through increased use of their present facilities; through not having to finance, in part at least, new generating and transmission equipment; through lower investment costs; and through the advantages of improved stability of service and added sources of energy.

Already there is in practice some degree of interconnection between companies and systems not under the same ownership. These are operated over limited areas in New England, in the East Central states, in the South and on the Pacific Coast. To illustrate, the Pennsylvania-Ohio-West Virginia interconnection in 1931 had an estimated peak of 1,750,000 kw. and served a population of 9,000,000 in 300 cities and towns.

But the present rate of effecting such interconnection is too slow to meet the public need, because it is retarded by intercompany rivalries and other conditions not grounded on social interest and yet readily removable. Therefore, just as the original impetus to interconnection was given by the Government during the World War in requiring any company having excess capacity to transmit its surplus current to nearby territory in need of it, now the Government must take the lead if we are to achieve the unification desired in the new war upon economic waste and instability, unemployment, and the progressive destruction of basic natural resources.

How to Interconnect

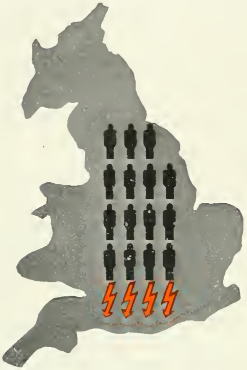
The accomplishment of the necessary large-scale interconnection can probably be had through progressive application of what is essential in the common carrier principle.

It should be remembered at this point that the plan here projected does not involve the question of public or private ownership of either generation or distribution. Government

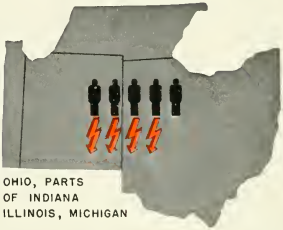
THE "GRID" IN THE U.S.

APPLIED TO 5 COMPARABLE AREAS

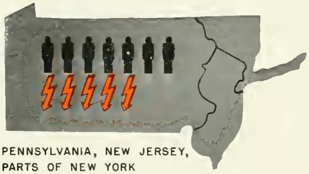
EACH MAN REPRESENTS 3 MILLION MEN
EACH BOLT REPRESENTS 3 MILLION KWH OUTPUT



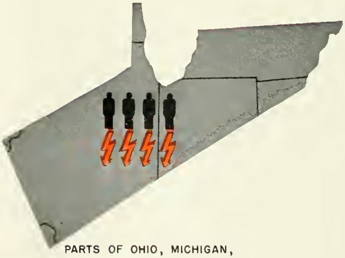
THE BRITISH GRID



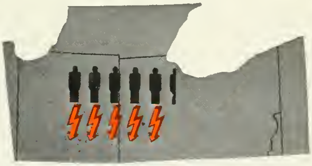
OHIO, PARTS
OF INDIANA
ILLINOIS, MICHIGAN



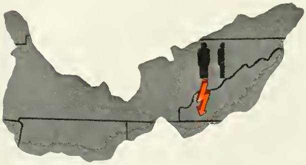
PENNSYLVANIA, NEW JERSEY,
PARTS OF NEW YORK



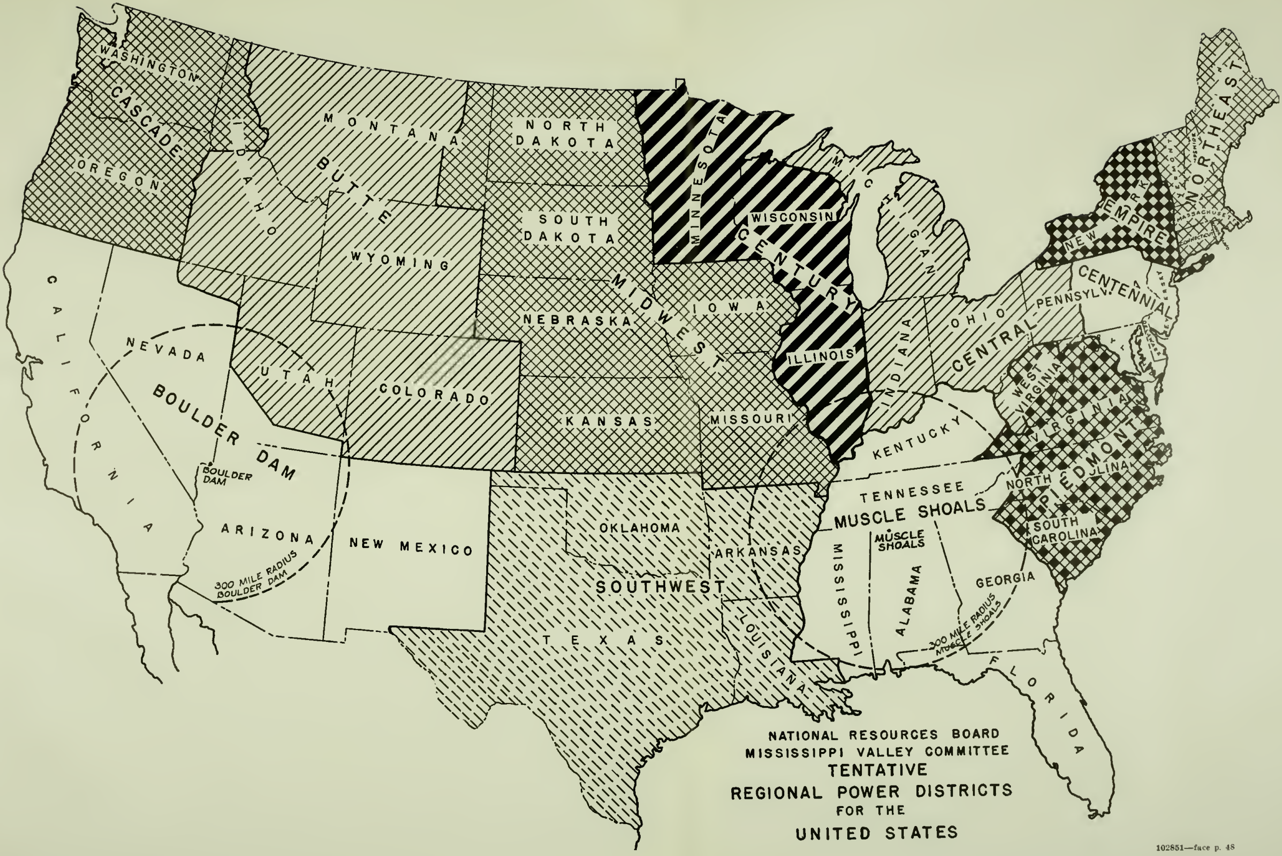
PARTS OF OHIO, MICHIGAN,
INDIANA, ILLINOIS, WISCONSIN



PARTS OF PENNSYLVANIA, OHIO,
INDIANA, ILLINOIS, MICHIGAN



TENNESSEE VALLEY



NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE
TENTATIVE
REGIONAL POWER DISTRICTS
FOR THE
UNITED STATES

control of transmission, however, is fundamental. This goal does not involve necessarily any great increase in the number of publicly owned lines, especially if the private companies cooperate in effecting unification.

Doubtless the Government will have to build some connecting lines to bring its own hydrocurrent to market in cases where companies have no need to build for their own purposes, or where the Government enters new areas in its promotion work for the common welfare, for example in the field of farm electrification.

Because the Government must have outlets for the power developed as an integral part of its conservation program, if the present system operates to block these outlets the national interest must obviously lead to a change in the system. The character and extent of the change will depend on conditions as they develop.

Public control sufficient to effect unification of transmission to compass the desired end is important—not the percentage of publicly owned plants. To ensure a balanced judgment on the whole problem it is well to remember that the item of transmission represents only about 20 percent of the total investment in the electrical industry, as indicated on the graph herewith.

The limited use of the common carrier principle, already made in various parts of the United States by private companies, has yielded satisfactory results. It is the central factor in the Ontario Hydro Electric System where a virtual government monopoly exists. But the best illustration of the complete utilization of the common carrier principle where public and private agencies cooperate under the direction of the State is found in Great Britain.

The British " Gridiron " System

After the World War, Great Britain was faced by a condition of their electrical industry somewhat similar to ours at present. The British answer to the problem is pertinent. Its chief objective is the same as our own—greatly increased and more widespread use of current made possible largely by lowered cost; its instrument the same as here suggested—public control, especially of fully coordinated transmission.

One of the chief reasons advanced in favor of the Grid proposal in Great Britain, and one which led the Conservative Baldwin Government to favor it, was as with us the prospect that surplus capacity would be reduced ultimately from the then existing 45 percent to about 15 percent, because power would be supplied from the common power pool and capital outlay for excess generating facilities would be minimized.

We may pass over a series of investigations and the enactment of 1919, based on voluntary cooperation, which failed to secure necessary unification, and note that the Parliament met the impasse in 1926 by passing the Electricity (Supply) Act based on the findings of a special inquiry commission headed by Lord Weir, which adopted the principle of forced cooperation in the public interest.

THE WEIR REPORT

"The report (the essential provisions of which were adopted) recommended the establishment of a comprehensive network of transmission mains, called the 'Gridiron', interconnecting all selected stations (43 existing ones and 15 new ones proposed) where generation would be centralized . . .

"It further recommended the creation of a new body termed the Central Electricity Board with powers to construct, own, and operate the proposed 'Grid' system of high tension transmission lines; that selected stations should be operated by the owners under the direction of the board; and that all high-tension energy generated by authorized undertakers in the country after a certain date should be generated under control in accordance with a technical scheme for the country, and sold through the board to all authorized undertakers, at cost price . . .

"It proposed 'not a change of ownership, but the partial subordination of vested interests in generation to that of a new authority for the benefit of all, and this only under proper safeguards and in a manner which will preserve the value of the incentive of private enterprise.' "[1]

The " Grid " Applied to the United States

The application of the British Grid System to the United States with its relatively greater areas to be coordinated is, in a way, visualized by five comparisons where such controlling factors as area, population, generating capacity, and population density considered together are similar enough to make such comparisons valuable. The maps herewith show the British Grid laid down upon five fairly comparable areas in the United States. Obviously American practice in the application of the Grid idea will be made to suit American conditions.

When the Federal Power Commission survey of facilities and demand is completed it will be possible to chart intelligently regional networks with the suggested tie lines connecting them. In the absence of data on which to base exact conclusions a tentative and illustrative regionalization is shown on the accompanying map.

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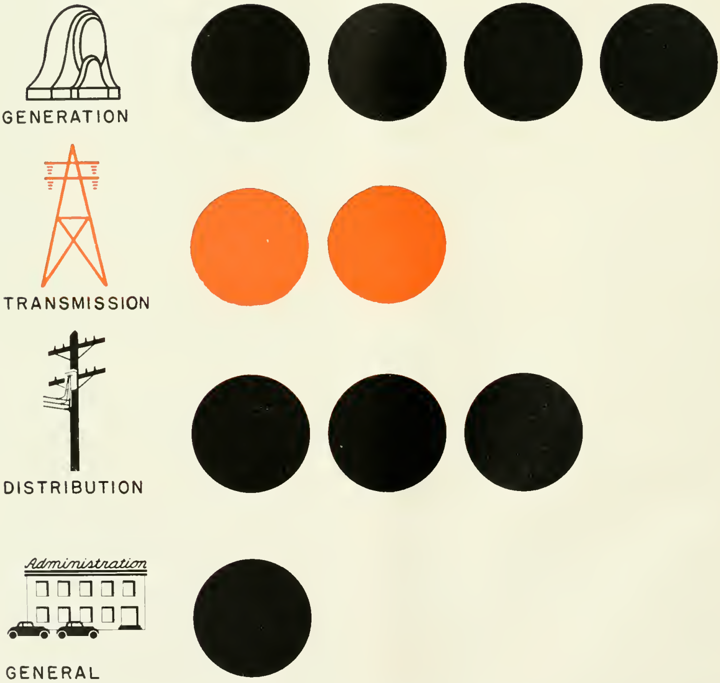
[1] Quoted from the Encyclopedia Britannica

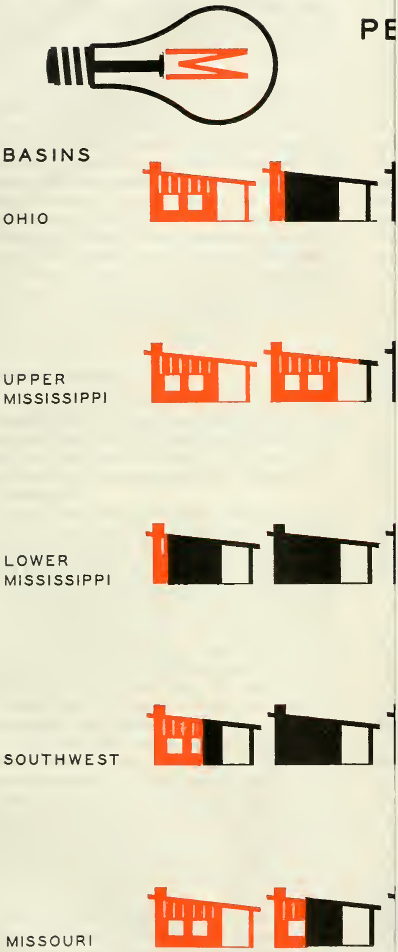
INVESTMENT

IN THE ELECTRIC INDUSTRY

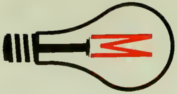
EACH CIRCLE REPRESENTS 10% OF TOTAL INVESTMENT



PE

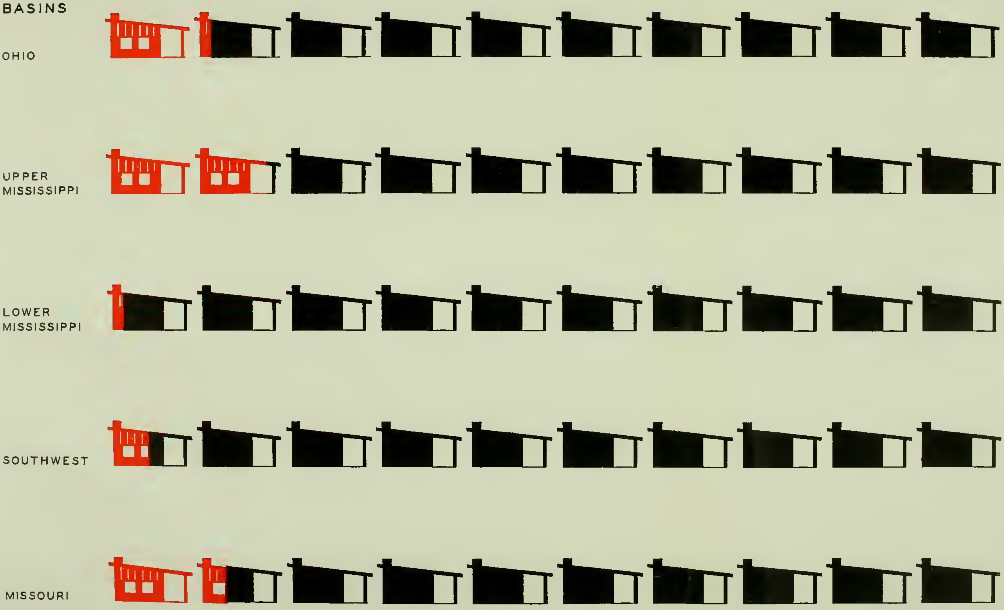


SOCIOGRAPHICS
PHILADELPHIA



PERCENTAGE OF FARMS HAVING ELECTRICITY

EACH COMPLETE SYMBOL = 10 %



SOCIOGRAPHICS
PHILADELPHIA

With the gradual development of interconnections the gap between installed capacities and actual use will be progressively narrowed, thus reducing present costs for electricity actually used and retarding the need for increased generating capacity.

During the initial period Government hydro plants, built in connection with a larger program of water use and control, can be started which will provide added current as it becomes needed. That is to say, the Government will have sufficient general information in hand to begin at once to plan broadly for complete development of its river public works in the Mississippi Valley, works involving a total of about one billion dollars and to be completed, say, over a period of 20 years. Perhaps 50 percent of this total will be for power installations and therefore self-liquidating. The sum also includes local contributions such as for flood control.

Rural Electrification

Along with the recognition that agricultural rehabilitation is a basic national problem, it is assumed that electric power has an important part to play in its solution. The task is to achieve rural electrification fairly promptly on a wide scale.

Says President Roosevelt: "Fifty million men, women, and children directly within our borders are directly concerned with the present and future of agriculture." And again: "Electricity can relieve the drudgery of the housewife and lift the great burden off the shoulders of the hard-working farmer." Emphasis is given to these words by the fact that there are an astounding number of distinct practical uses to which the farmer and his wife can put this "willing servant", many of them economically profitable, others cultural.

Of the six million farms in the United States over 800,000 are "electrified." But only about 650,000 have "high line" service. The balance have individual plants, expensive to operate and limited as to use. Over 5,000,000 farms are entirely without electric service. Estimates as to the number of these which can now economically be given service range from one to three million. The wide-open character of this opportunity is emphasized by the much larger percentage of farms having telephones and automobiles than those having electricity, as shown on the accompanying graph.

Unless the Federal Government assumes an active leadership, assisted in particular instances by State and local agencies, only a negligible part of this task can be accomplished within any reasonable time.

The big problem in rural electrification is not the cost of generating energy but the cost of delivering it to the rural customer. In Canada, Great Britain, France and other countries this fact has been recognized. In Ontario, where rates are low, the Provincial Government, in its policy of promoting the basic industry of agriculture, has contributed 50 percent of the costs of primary lines and equipment necessary to supply rural customers. This contribution of some $9,000,000 has resulted in the construction of over 9,000 miles of rural primary lines, serving 60,000 customers with a maximum demand of 27,000 kw. The Province also grants long term loans for house wiring and for purchase of appliances. In Great Britain experiments have been initiated with the object of ascertaining what results may be expected from the development of a rural supply of electricity in representative rural areas.

Several reasons might be advanced to explain why only 10 percent of the nation's farms (less than six percent in the Mississippi Valley) purchase electricity. These are the lack of interest by operating companies in rural electrification, high cost of line construction because of the unnecessarily expensive type of line used, onerous restrictions covering rural line extensions, and high rates.

How to Make the Start

Having recognized the advantages of rural electric service and reached the conclusion that only under Governmental leadership and control is any considerable electrification of "dirt farms" possible, we face the obvious obligation of getting it done. Perhaps the start should be through an allotment of $25,000 or $50,000 to survey specific localities. But an allotment of $100,000,000 actually to build independent, self-liquidating rural projects would exert a mighty influence in various directions.

The proposal does not involve competition with private interests.—This plan calls for serving territory not now occupied and not likely to be occupied to any considerable extent by private interests. The proposal has become possible only recently through the marvelous development of the Diesel engine, which could be used for power in regions where high line extensions are not feasible. Another source of power would be small hydro plants where suitable sites are available. In cases where it is practicable, public transmission lines utilizing either government or private power sources could be erected. Rural distribution lines will cost from $500 to $800 per mile to construct, and to amortize this cost in 20 years involves a cost to each of three consumers on a mile of line of about $1.00 per month.

While there are variations in the cost of rural service, it is obvious that the key to low rural rates as to all rates, lies in extensive use of current. In doubling the use of current the cost per unit is all but cut in half.

Planning on a wide scale, say of service to 500,000 farms in units of 1,500 farms, the total cost, if generating plants are included for each unit, would be $165,000,000 or $330.00 per farm; but if one-half of the units can be supplied from existing sources the total cost would be about $140,000,000 or $280.00 per farm. In both cases the outlay would be amortized through an appropriate element in the rate.

Regarding Expected Increase of Demand

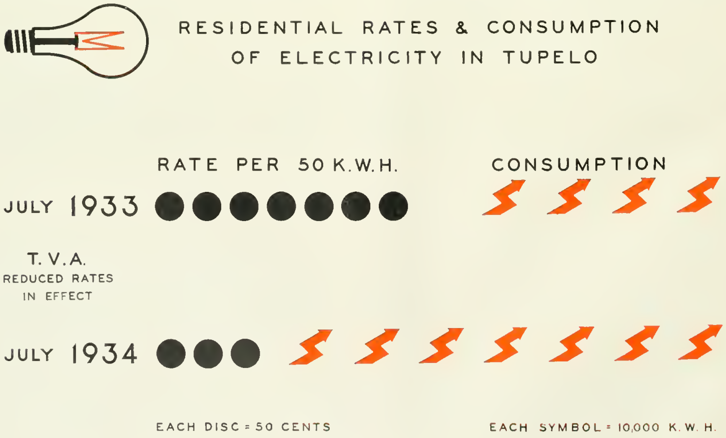
If it be objected that it is not sound economics for the Government to build stations when the present generating capacity cannot or does not find a market, the answer is that this criticism places the cart before the horse and ignores the social purpose underlying the policy proposed.

The present consumption of electrical energy is not to be assumed as a base upon which to estimate the demand upon such a system as is here considered. Not only are there considerable areas which have no electric service at all, in particular hamlets and farm districts, but because of the prevailing high rate schedules in areas now served usage is sharply restricted.

Recent studies of domestic consumption in low-cost municipalities demonstrate that the load factor invariably mounts for a preponderant percentage of customers in response to lowered rates, and this affords a reasonably firm base for calculation of future demands.

In Seattle, yearly domestic consumption has reached an average of 1,108 kw.-hrs. per home; in Tacoma, 1,550 kw.-hrs. Twenty-six cities of Ontario show an average of 1,779 kw.-hrs., and Winnipeg, with an average net cost of eight mills per kw.-hr. has an average yearly consumption in excess of 4,000 kw.-hr. It has been demonstrated that it is low rates and not the fact that these cities lie in the belt of high coal costs that accounts for this high average use. When such results are set against our national average of 604 kw.-hr. per year in 1933, a point reached after a slow climb from 339 kw.-hr. in 1920, it becomes apparent that the expectations entertained here are not unreasonable.

Competent planning will take cognizance not only of the increased domestic load and the demand which wholesale farm and railroad electrification will bring, but also of many other considerations of public convenience and safety which may, for instance, soon bring about from two to four times the amount of municipal street and alley lighting now in use. Cheap power for pumping will become an important element of water conservation and afford a desirable night load at specially low



RESIDENTIAL RATES & CONSUMPTION OF ELECTRICITY IN TUPELO

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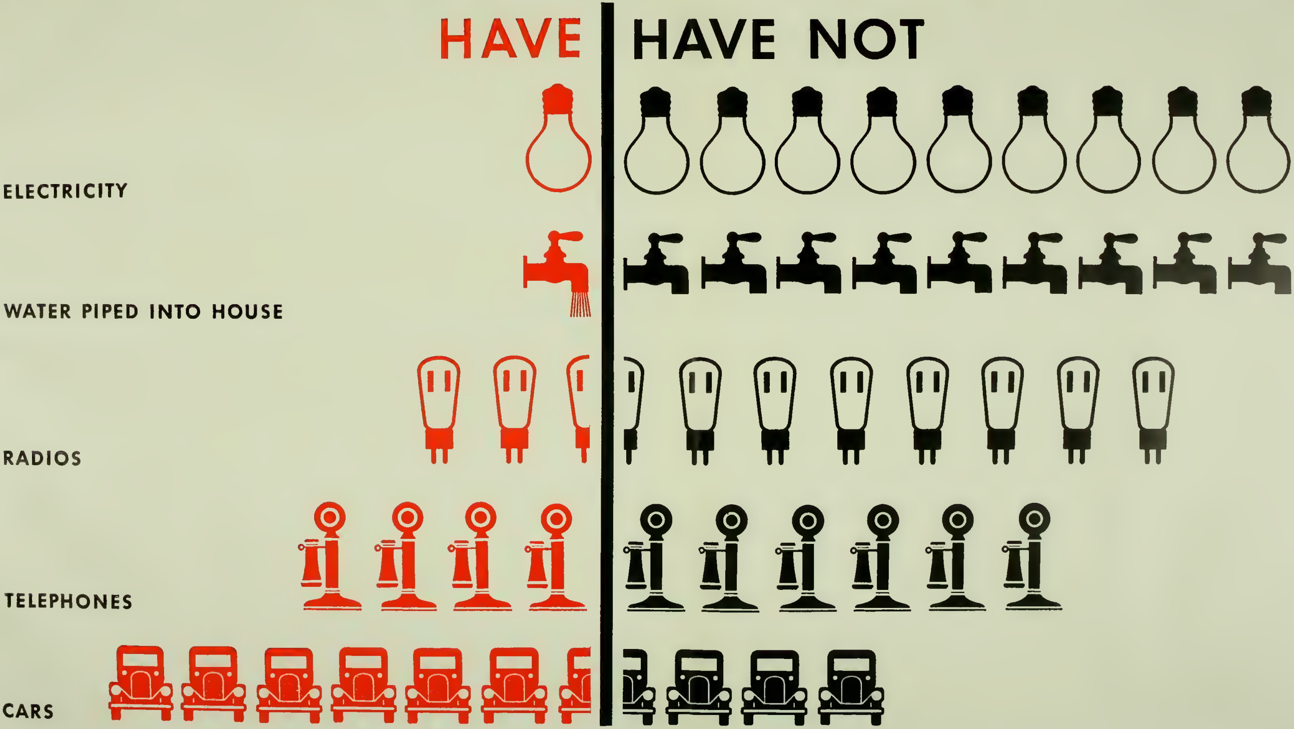
FARM MODERNIZATION IN THE MISSISSIPPI VALLEY



EACH SYMBOL REPRESENTS TEN PER CENT OF ALL FARMS EQUIPPED WITH ELECTRICITY, WATER, RADIOS, TELEPHONES, CARS

rates. The increasing hazards of congested automobile traffic will soon lead to the lighting of dangerous sections of country roads at night and even to whole arterial highways between large cities. These are but samples, all of which anticipate a demand upon generating and transmission facilities far beyond our prevailing ideas of use.

Conclusion

The plan here proposed for power development in the Mississippi Basin involves three great factors: (1) the Grid system as a tie-in; (2) a great program of public works, and (3) such a wider use of electricity as would be attained through rural electrification. Power thus becomes a component part of a larger plan aiming at the solution of the fundamental problems of flood control, low water control, navigation, irrigation, soil conservation, forestation, recreation, and other matters, on which depend not only ordinary human welfare as we have been accustomed to view it, but the very preservation of the physical foundations on which our civilization rests. The consummation of these objectives lies outside the field of private initiative. The nation must take the lead.

In respect to power, the plan does not rest upon any captious criticism of the electrical industry, or place any burdens upon its wholesome practices, its initiative or usefulness. On the contrary, rightly viewed, the industry's position will be strengthened by coordination with the efforts of the Government in working out its comprehensive plan and in cooperation with the States, municipalities and power districts in solving their respective problems.

The plan here considered in both its immediate and long range aspects is directly related to another social problem of like fundamental import—unemployment. There is involved not only the acute question of finding work for the millions displaced by the present depression, but for those involved in the more serious menace of *chronic* technological unemployment. It is estimated by some that around 5,000,000 men will be indefinitely displaced by machines and measures which competing industries will be forced to adopt or cease to operate.

A comprehensive Mississippi Valley public works program, involving ultimately among other items the building of possibly 500 dams of some magnitude, would absorb a considerable portion of this unemployment total, and do so over a long period. Men and women if not self-sustaining must be supported at public expense. The financial sanity and soundness of the enterprise in its entirety is then further emphasized by the fact that not only will power be largely self-liquidating, but the labor factor will be self-liquidating also.

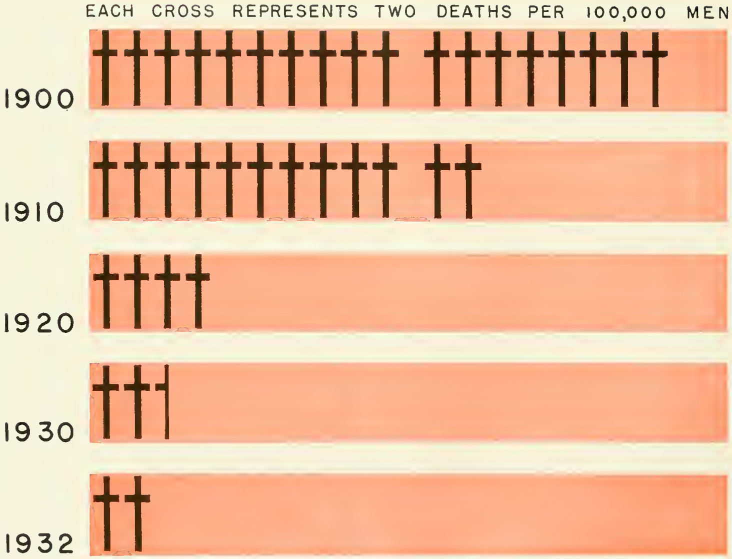
Of the returns in terms of social well-being, national safety, agricultural and industrial advance, and of individual happiness and security, there is no yardstick adequate for the measuring.

WATER SUPPLY AND SANITATION

TYPHOID

FEVER DEATH RATE IN THE U.S.A.

LARGELY CAUSED BY UNSAFE WATER



Importance

Provision for an ample supply of pure water for domestic use and prevention of contamination are problems of major importance in planning for water use and control. All phases of these problems are encountered in the Mississippi Drainage Area, and clear evidence of a need for comprehensive planning is discovered in problem areas of the different drainage basins.

Certain general conditions apply variously to different areas in the Valley. In the dry regions west of the River, many cities draw their water supplies from nearby rivers which, in periods of extreme drought, become very low. Sewage discharged into these streams is not carried off promptly and the natural purifying process characteristic of water in normal flow is incomplete. Likewise, in the humid regions of the Valley, the problem of stream pollution is acute during the seasons when rivers are subject to low stages. In all regions, cities obtain water from and discharge sewage into the same stream utilized by industrial plants to carry off deleterious waste materials. Here problems of water treatment arise not only seasonally but throughout times of normal flow. At low stages, however, the situation becomes critical.

River improvements which serve in maintaining dry-weather flow of streams; studies of industrial waste treatment; cooperation between municipalities in solving problems of supply; purification and disposal; direction by Federal and State agencies of attack on these problems, all constitute an important part of a national program for water use and control.

A Public Problem

A census of waterworks made in 1931 by the Conference of State Sanitary Engineers indicated that roughly four out of five urban dwellers in this country were provided with water by municipalities and private hydraulic companies. Formerly a large number of municipalities were supplied by private utilities. Within the last 25 years, there has been a trend toward public ownership of waterworks.

The problem of securing adequate water supplies, even for present demands, is difficult of solution. It is therefore important for municipalities to develop adequate plans, looking reasonably far into the future, to provide for their needs. Planning of future supplies is especially necessary when the source of supply is a river draining a well-settled valley. It should include future construction of purification works and extensions of the distribution system to meet the needs of growth. Furthermore, comprehensive planning must take account of the difference between the problems and possible solutions in urban and rural areas.

1. *Urban:* Neighboring communities can best and most cheaply be served by a centralized waterworks and distribution system. Service of water by districts can be attained by agreements between municipalities involved, through the chartered area of a water company, or by creation, pursuant to law, of water districts. In some States such districts have separate taxing and borrowing powers over and beyond the municipalities included in the district.

Processes of purification have been developed to remove or modify nearly all the different kinds of organic and inorganic impurities present in raw water. These processes, if properly applied, can produce a bacteriologically safe water and, usually, a palatable supply even though the raw water is too polluted for safe use. There is, however, a definite trend among waterworks engineers and a rapidly growing demand on the part of the intelligent public for use of relatively clean water as the source of supply, with minimum artificial purification.

2. *Rural:* In rural districts the population must depend on individual effort to secure water for drinking and domestic use. Where water table is relatively high, private supplies are generally obtained from springs and dug or drilled wells. In sparsely inhabited areas, ground waters, except those from fissured limestone, broken shale, or other loose strata, are usually fairly pure. Maintenance of this purity depends on care taken to protect wells and springs from pollution.

The Supply

1. *Chemical Character:* The chemical impurities of the surface and underground water in the Mississippi Basin and the suspended matter in the surface waters range from almost nothing at some places and times to quantities that make the waters entirely unfit for nearly all uses at other places and times. Even in the public supplies of cities are found wide ranges in hardness, for example, of from three parts per million for Greenville, Miss., and four for Asheville, N.C., to 800 for Aberdeen, S.D. Similarly, suspended matter ranges greatly; in the Wisconsin River near Portage, Wis., averaging 4.6 parts per million for one year; the average for the Missouri River near Kansas City, Kans., was 2,000 for the same year.

Only a comparatively small amount of reliable information is available on the chemical character of waters in the Basin. As a basis for planning for use or treatment of a river water, at a given point, there should be a series of chemical and physical analyses of composite daily samples collected over a period of a year or more, with corresponding discharge data. For the Mississippi Basin, apart form Illinois and Kansas, there are not more than 25 reliable water analyses based on observations carried on over a year or more.

2. *Sources:* Planning for protection of a water supply must take into account flood control, forest cover, soil erosion and river-flow regulation. Where waterworks are located on banks of rivers subject to flood, open parts of the works should be made higher than record floods. When this is not done, or when an unprecedented flood occurs, polluted flood waters menace the purity of the domestic supply.

Upland waters derived from forest lands are likely to be much cleaner than the water of most main rivers and, even following heavy rainstorms, less turbid than water taken from streams draining deforested areas. Soil erosion is an important cause of high turbidity of streams. The first step in any water-purification plant is sedimentation to remove turbidity. Decreased soil erosion, therefore, would lighten the silt load on waterworks below.

In streams draining developed areas, the sanitary quality of the water is poorest during the low flows of summer, especially during drought. River flow regulation to increase these low flows would materially benefit waterworks by diluting the pollution content of the raw water and thus would improve its sanitary quality. Simultaneously, the quantity of water would be increased at times of greatest need.

Treatment and Disposal

1. *Sewers*: How far sewage treatment should be carried is determinable by the use and condition of the body of water into which the effluent is discharged, but from a practical point of view, a less degree than the ideal is sometimes the only one attainable. Construction and operation of public sewer systems are municipal functions subject to State law which generally provides for approval of sewer projects and for granting by State Health authorities of permission to discharge sewage into streams. Sewers for contiguous or neighboring municipalities can be provided either by agreements between them or by creation of sewer districts where authorized by law. In the latter case, such districts are frequently given taxing and borrowing capacities over and above that of the municipalities in the area served.

Comprehensive sewer system planning, with special reference to the design of the main and intercepting sewers, pumping stations, and sewage treatment works, is economical of public funds because it makes possible utilization of virtually all new construction as a part of a complete ultimate project.

2. *Industrial Waste:* The treatment of specific industrial wastes has been extensively investigated. During the past 10 years, advance in knowledge of treatment along broad lines has been attained through group effort of certain industries, generally in cooperation with State Health Departments; for instance, the tannery, byproduct coke oven, oil refinery, pulp and paper, cannery and milk and milk products industries. Many other kinds of industrial wastes, however, have not been adequately studied. It is important to extend our knowledge in this field by further research under the leadership of the U.S. Public Health Service.

3. *Natural Purification:* Nature provides for ultimate self-purification of streams through chemical and bacterial action and through dilution. So far as practicable, advantage should be taken of this process in any comprehensive plan.

4. *Conclusion:* The problem, therefore, resolves itself into one of degree of treatment of sewage and industrial waste necessary at specific places to produce effluents which can be inoffensively assimilated by the receiving body of water without harm to public interests at points downstream.

Interstate Streams

The problem of water supply and sanitary conservation of water resources on the Mississippi River Drainage Area, as elsewhere, is complicated by its interstate character. In the absence of formal compacts between States, sources of public water supplies, derived from interstate streams, can be somewhat protected against harmful pollution arising in another State by agreements between Health Departments of States on the drainage area. For example, Health Departments of the 11 States in the basin of the Ohio River are parties to a 10-year-old agreement providing for cooperation to protect public water supplies.

Diversion problems have arisen several times and reached the Supreme Court of the United States, which, in the Connecticut [1] and

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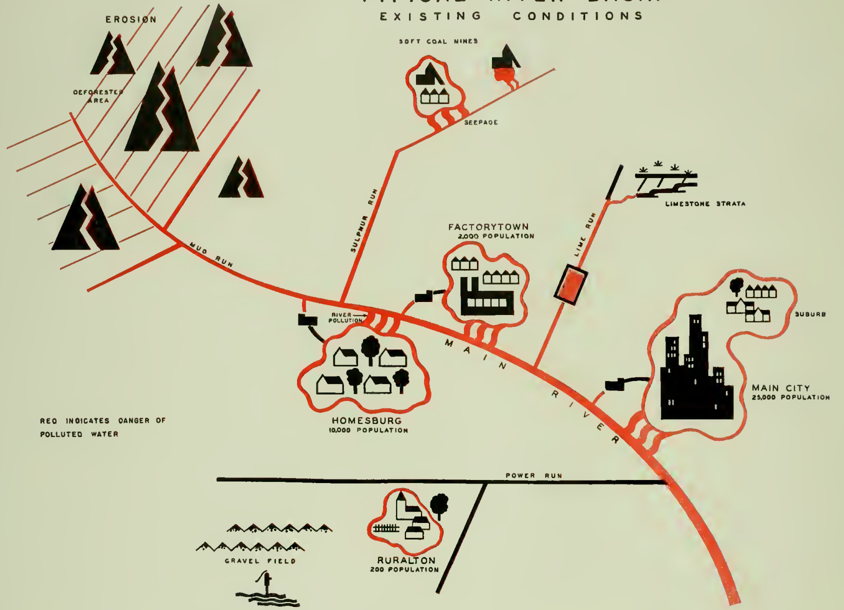
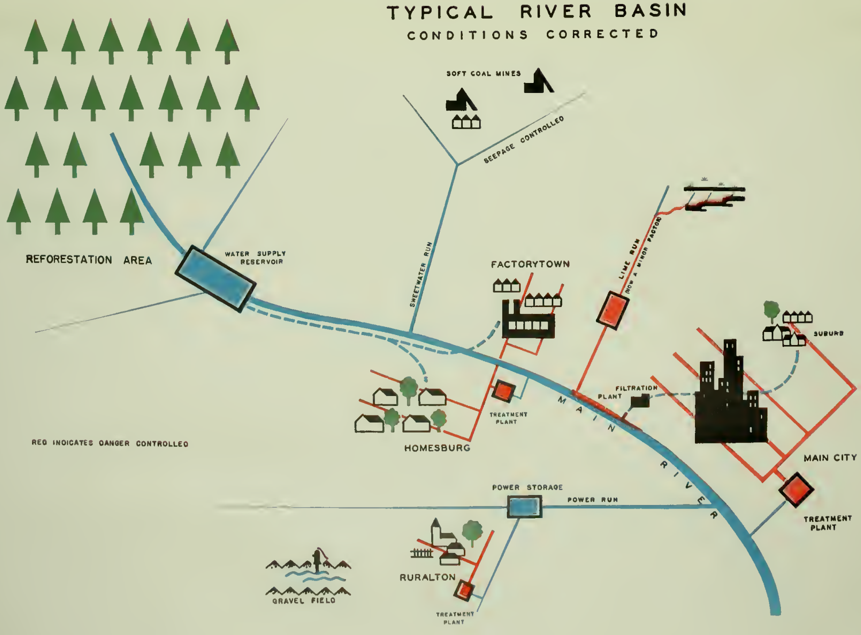
[1] 282 U.S. 660.

TYPICAL RIVER BASIN
EXISTING CONDITIONS



RED INDICATES DANGER OF POLLUTED WATER

TYPICAL RIVER BASIN
CONDITIONS CORRECTED



RED INDICATES DANGER CONTROLLED

Delaware[2] River cases, upheld and declared the doctrine of equitable allocation that each sovereign State is entitled to take and use its fair share of interstate waters, provided, that material and substantial damage is not done to another sovereignty.

Intrastate Streams

Control of water supplies and sanitary conservation of intrastate water resources require consideration of several important subjects.

There is a conflict between the necessity of maintaining a stream in as pure condition as possible for water supply use and the need to use that same stream for disposing of sewage and industrial waste. Adjustment of this conflict requires knowledge of the basic facts of the problem, which can only be had through more extensive inventory of water resources to show present use and condition of streams and the sources of their harmful pollution. Some data are available as a result of field surveys by Federal and State agencies but, as yet, these are not complete.

The most thorough investigation so far of the interrelations between public-water supply, waste disposal, stream pollution, and stream recovery has been made on the Ohio River by the U.S. Public Health Service and published in a series of monographs. The deductions from these studies are generally applicable to other problem areas.

It is in the public interests for water resources to be developed for the highest and most useful purposes. To do so, proper State authorities should be empowered to allocate waters. This objective can be attained by a statute prohibiting use of water resources for water supply, development of power, industrial purposes, etc., without first obtaining a permit from the proper State authorities. An allocation policy would provide that certain areas be designated as the proper source of public-water supplies. Regulation should prevent pollution of streams draining such areas. Streams draining intensively developed valleys could be allowed a lower standard of sanitary quality, provided that, so long as public-water supplies are derived from such streams, the pollution load would not place an undue burden on waterworks.

Impounding of surface waters in reservoirs may cause a substantial diminution in the rate of flow of streams below. So far as the sanitary quality of waters draining developed areas is concerned, the low flows of summer occur at the most adverse and critical times. Hence, compacts between States and State permits should cover the releasing of reasonable and practicable rates of compensation water from reservoirs during periods of low flow.

Law

In an urban, industrial era and from an engineering and economic view, the early riparian doctrine—that each riparian proprietor was entitled to receive the flow of a stream undiminished and unimpaired in quality—as literally interpreted is now impracticable and obsolete. Public water supplies must be withdrawn from streams and served to all consumers whether they be riparian lot owners or are far back from the streams. Storing of water for power development, flood control, river regulation, and industrial use must of necessity at times diminish stream flow. The sewage of towns, trade wastes of factories, and waste water from the development of natural resources, even though treated to a considerable degree, do to some extent impair the quality of streams.

As this country was settled and semiarid areas of the midwest developed, quantity of water was of prime importance and its use essential for development of the land. There the riparian doctrine of the east was modified. Later and still farther west, under arid conditions, the doctrine of prior appropriation became the law. That is, the first user of the water of a stream for beneficial purposes had prior rights over his neighbors regardless of their position along the stream, nor was his use limited to domestic purposes.

The doctrine of equitable allocation of interstate waters to meet present and reasonable future needs in accordance with a hierarchy of of use is applicable to intrastate waters. Allocation of waters and regulation as to use by proper public authorities, if administered upon engineering and economic principles and with the objective of attaining the best interests of the States, would be superior to any doctrine of water use built upon legal theories and past practice. This, however, might require changes in Federal laws and, in some cases, of State constitutions.

Policy

To insure adequate and healthful water supplies and to provide improved sanitation, a policy should be pursued to foster—

1. Enactment of statutes (where needed) to vest in the State Health Department adequate jurisdiction over public water sup-

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[2] 283 U.S. 336.

plies, sewer systems and treatment and disposals of sewage and of industrial waste.

2. Creation of State agencies having power to make inventories of water resources and to allocate and control intrastate waters for most beneficial purposes in the public interest.

3. Enactment of enabling statutes (where needed) for the creation of water-supply districts and sewer districts, the formation of such districts where the principle is applicable, the preparation by municipalites of comprehensive sewer system plans and by water surveyors of comprehensive water-supply plans.

4. Provision for the gathering, correlation and distribution by Federal and/or State agencies of information on the chemical characteristics of water supplies in the Mississippi Drainage Area, and for the systematic collection of hydrological data relating to water resources.

5. Authorization of the U.S. Public Health Service to make sanitary surveys of interstate streams used as sources of public water supplies and receiving substantial pollution, and to furnish these data to the relevant State Health Departments for guidance in determining policies for correction of pollution.

6. Authorization of the U.S. Public Health Service to correlate existing data as to known reasonable and practicable processes for treatment to progressive degrees of industrial waste; to inaugurate scientific investigation to evoke improved industrial waste processes where such do not now exist, and also to publish and distribute results to the public.

7. Compacts by States in the drainage basin of major river systems with reference to water-supplies, sanitation, and general development of the water resources for most beneficial use.

POLICY OF EROSION CONTROL

The Situation

The present rapid depletion of the soils of the country by erosion creates a problem profoundly affecting the interests of the entire nation. Recent studies indicate that the fertile top soil is progressively being worn away by erosion on nearly three-quarters of the tilled land of the country, that about 25 percent of tilled land in the Mississippi Basin alone has already lost a large part or all of the top soil; and that no less than 5 percent has been ruined for further crop use by gullying. Erosion removes large quantities of plant food, compacts the soil surface, reduces the power of the soil to absorb water, and lessens its crop productivity. Erosion increases surface run-off, has a disturbing effect on stream flow, and loads streams with silt. Direct losses from soil erosion are estimated to be not less than 400 million dollars annually; the indirect social-economic losses cannot be measured in money values. A fact of special significance is that impairment of our soils, such as is now taking place, is permanent in character. The richness inherent in the top layers of virgin soils, when once removed by erosion, cannot fully be restored by artificial means. Erosion is progressively undermining the foundations of a permanent agriculture in a great many sections. In some of the older countries soil erosion following land abuse has started a chain of economic consequences that has had a profound effect on the very character of civilization.

No nation can afford to permit such progressive decline in the productive value of its soil resources as is now taking place in this country. The situation calls for a program of immediate public action on a far larger scale and much more effective than is represented by the efforts heretofore undertaken by Government agencies.

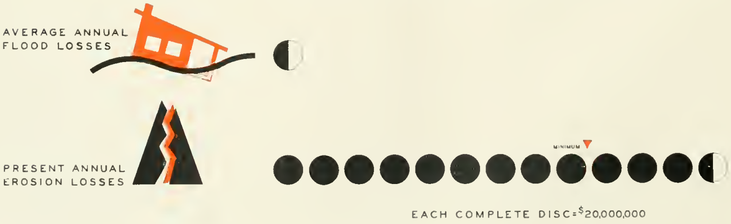
The problem of checking erosion is chiefly one of control of the surface run-off of water on sloping ground. In undisturbed natural conditions, the erosive forces act very slowly on account of the forest cover, grass, and other vegetation. When this protective cover is disturbed by forest destruction, tillage, or overgrazing of livestock, erosion is accelerated, and special measures are necessary to minimize the wearing and cutting action of the water. The construction of terraces on slopes lessens the velocity of the water flowing over the surface, increases the amount absorbed by the soil, and provides for the diversion of surplus water. Other methods of control seek to retard the rate of surface run-off of water and to increase its absorption by soil through skillful tillage and use of appropriate crop covers.

Sheet and Gully Erosion

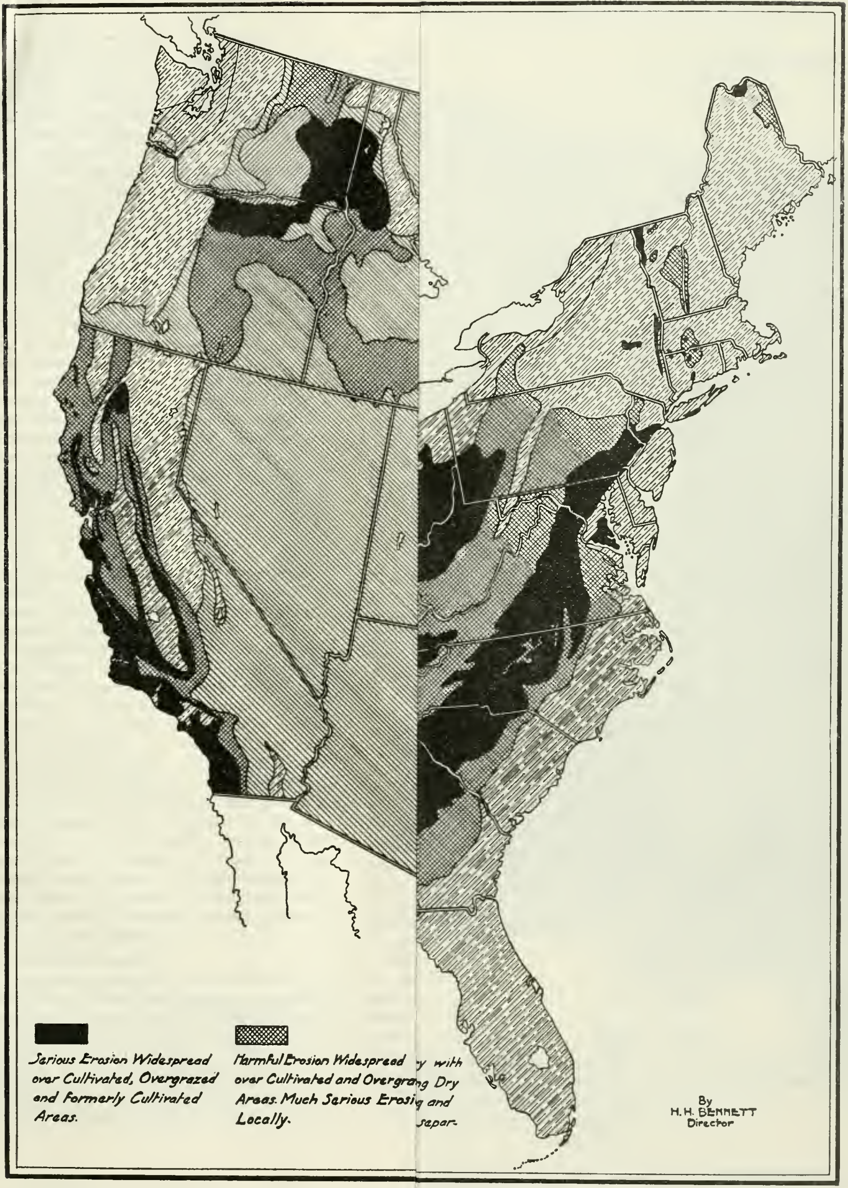
The most urgent problem of erosion, from the public standpoint, is to check the progressive depletion of the productive soils from surface wash. This is a problem of preventive work to keep the soils from losing the rich layer of topsoil and also prevent the start of gully erosion which destroys the soil for crop use. Although sheet erosion is less spectacular than gully erosion and it is often not noticed at all by the casual observer, it is far more widespread and its injurious consequences in the aggregate much greater.

The problem of control of gully erosion is primarily to prevent further encroachment of gullies on valuable land and to reduce the disturbing effect on stream flow and the volume of silt discharged into streams. Ordinarily gully control will not restore land for agricultural use. Heavily gullied land can, however, be used for tree growth, when erosion has been checked.

FLOOD AND EROSION DAMAGE IN THE MISSISSIPPI BASIN WEST OF THE RIVER



DEPARTMENT OF THE INTERIOR SOIL EROSION SERVICE


■ Serious Erosion Widespread
over Cultivated, Overgrazed
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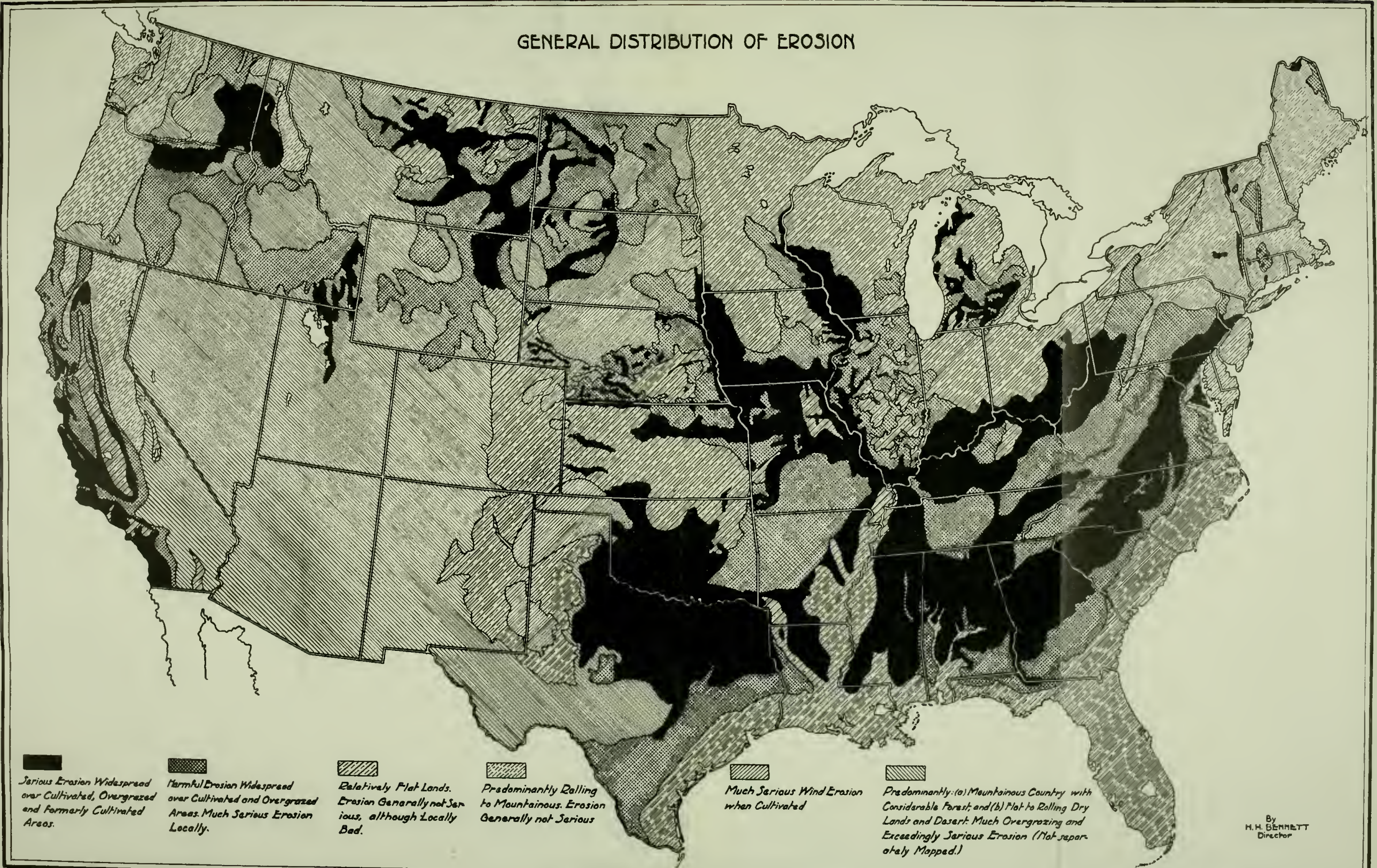
By
H. H. BENNETT
Director

DEPARTMENT OF THE INTERIOR

SOIL EROSION SERVICE

GENERAL DISTRIBUTION OF EROSION


Serious Erosion Widespread over Cultivated, Overgrazed and Formerly Cultivated Areas.
Harmful Erosion Widespread over Cultivated and Overgrazed Areas. Much Serious Erosion Locally.
Relatively Flat Lands. Erosion Generally not Serious, although Locally Bad.
Predominantly Rolling to Mountainous. Erosion Generally not Serious
Much Serious Wind Erosion when Cultivated
Predominantly: (a) Mountainous Country with Considerable Forest; and (b) Flat to Rolling Dry Lands and Desert. Much Overgrazing and Exceedingly Serious Erosion (Not separately Mapped.)
By H. H. BENNETT Director

The Problem of Ownership

The character of ownership of land subject to erosion requires first consideration in formulating a public policy of erosion control. The most serious problem is in connection with the control of erosion on tilled land and on range and pasture.

The tilled land is owned by several million farmers, much of it in small tracts. The direct and indirect injury from erosion is in the aggregate greatest on the fields of farmers. Most of the farmers have used traditional methods of cultivation, without appreciating that their land has been rapidly deteriorating through sheet erosion. Many of them attribute the lowering of productiveness of their fields to the loss of plant food, whereas the real cause is soil erosion.

In many cases the individual farmer is ignorant of the practical techniques of control, or he does not possess the means or equipment to undertake effective control measures. In some cases lack of intelligent efficiency explains the failure to adopt modern methods of soil protection. The problem of the public is to find a way to bring about the adoption of effective methods of erosion control on a great number of individual farms. This applies both to the tilled lands and to the pastures and pastured woodlands owned by farmers, which in a great many cases are suffering from erosion because of over-grazing of livestock.

A considerable portion of the stock ranges in the West is owned by the Federal Government and, in less quantity, by the states. The remainder is owned by stockmen and by miscellaneous land holders, such as railroad companies, lumbermen, and others who are not in the livestock business. Control of erosion on the range is a problem of regulated grazing of livestock. The extension of the system of range management now in effect on the National Forests to the public domain would largely solve the problem of erosion on the federally owned lands. It is important also to bring about on privately owned range land similar preventive measures to check deterioration of the land by erosion.

Public Activities Control

The public activities so far undertaken in erosion control have been directed to research, experiment, demonstration, and public education, and, on the public forest reservations, to systematic range and forest management. Research and experiment are conducted by the U.S. Department of Agriculture, in cooperation with state agricultural experiment stations, on ten erosion stations located in regions specially subject to erosion. Since 1929 studies of the extent of erosion throughout the country have been under way and have revealed a situation far more serious than had been appreciated.

The Forest Service carries on extensive research through its field experiment stations in regard to the part played by forests in erosion control and the effect of forest fires and deforestation. The Federal and state extension services have cooperated in educating farmers regarding dangers of erosion and regarding practical methods of control. In 1933 the Soil Erosion Service was established in the U.S. Department of the Interior for the purpose of carrying on a series of demonstrations of erosion control on a large scale. Units of not less than 100,000 acres have been laid out and a plan developed for the introduction of appropriate control measures, in cooperation with the owners, on all lands within the units subject to erosion. Twenty-four such units have so far been organized.

The work of these public agencies has been excellent and already a great deal has been accomplished in practical results. It was largely through the work of public agencies that, between 1915 and 1932, eighteen million acres of farm land were brought under a system of terracing. In addition, a very large number of farmers were induced to use other measures of soil protection, directed to improved tillage, rotation of crops, strip-cropping and the like, and to the use of sod-forming crops or tree growth on steep land.

The Government has, during the last year or more, undertaken extensive work in checking gully erosion by building check dams, rectifying gully slopes, and planting trees and other vegetation. In this connection it is strongly emphasized that sound engineering principles are necessary in building check dams. In numerous cases there has been faulty construction and the dams will not withstand concentrated run-off following heavy storms.

All of these efforts taken together, however, are proving inadequate to meet the present situation. The present progress of introduction of control measures is too slow to save a large part of the tilled land from serious and permanent depletion. A good foundation has been laid for control of erosion. It remains now to build on this foundation by the development of erosion control on a national scale, initiated at once and carried forward as rapidly as possible.

Basic Principles of Policy

Need of Public Participation: The most urgent problem of soil erosion is on private land. It has heretofore been assumed that, with a reasonable amount of public education and cooperation, self-interest would induce land owners to adopt measures to prevent injury to their property. This assumption fails to recognize that we are dealing with a natural destructive force that operates unceasingly and is impairing the land at a rapid rate. The situation requires action that will not be taken if the problem is left to private initiative. The problem is analogous to that of the control of forest fires, which is now in the process of solution through systematic public cooperation and direction.

Objectives of a Policy: The purpose of a national policy of erosion control is to unite in a common program the efforts of all public agencies and of private landowners and operators in checking the process of soil erosion. This does not imply that the public should undertake all work and cost of control measures. The actual work should be carried out on the ground by owners or their agents, with only such cooperation from the public as may be necessary to apply effective preventive measures against erosion. In a program of this character, the Federal Government, states, counties, and private cooperative organizations have a part to play.

Federal Responsibilities: Great national interests are at stake in the conservation of the country's soil resources. There rests on the Federal Government the responsibility to take such action as may be necessary to bring about practical measures of land use that will effectively check the present rapid progress of soil deterioration. It is the duty of the Federal Government to formulate a policy and to take the active leadership in carrying out a Nation-wide cooperative program of erosion control. It will involve directive planning, liberal financial support, and such general administrative direction as may be required to bring into effective coordination the efforts of other public agencies and of private organizations and individuals.

State Responsibilities: The states have jurisdiction over the land and the power, if they choose to exercise it, to prevent land abuse. Heretofore, their efforts in erosion control have been confined largely to research and extension teaching, in cooperation with the Federal Government. In a national undertaking in erosion control, the states have an important function. Normally, the state would be the agency to organize and assume general administrative responsibility for cooperative work with landowners, receiving and disbursing federal funds, appropriating their proper share of the cost of the enterprise, and exercising their constitutional powers of control over private land, if needed to carry out an effective program of soil conservation. There are, however, difficulties in securing prompt action by the states in a national program of erosion control, such as is needed at the present time. There should be provision, therefore, in federal legislation for direct cooperation by the Government with counties, organized regional districts, and private owners, where the state governments fail to take action.

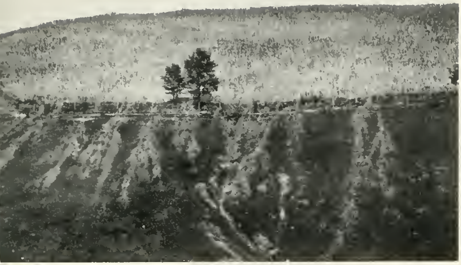
Responsibility of Private Owners: Private ownership of land carries the obligation to refrain from practices which will injure other persons or the general public. In the long run the burden of loss through soil erosion falls heavily on the community and on the people. There are many reasons, historic, economic, and personal, why destructive methods of soil exploitation have persisted. It is too much to expect most farmers to modify their methods of tillage and cropping without public cooperation. They should, however, be required to redeem their responsibilities of land ownership and to use preventive measures of erosion control, provided there is liberal help from the public.

Public Regulation: It should be the aim of a national policy of erosion control to avoid the necessity of imposing restrictive regulations under the authority of law on the manner of the use of land, provided that the public interests can be protected through other means. Cooperative aid, granted under the condition of adopting constructive measures of soil protection, would be far more effective in practice than direct public regulation. If, however, the cooperative principle should fail, the public in its own protection would have to resort to mandatory regulation.

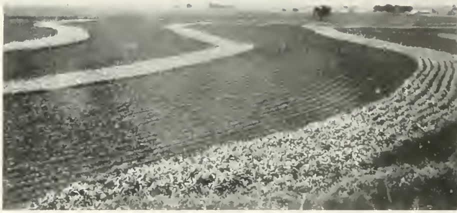
A National Program

A program of Nation-wide control of erosion, which would bring into coordination the efforts of various public and private agencies, would include the following features:

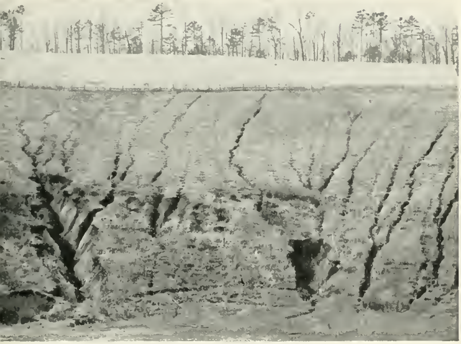
1. Federal legislation authorizing the Government agencies to cooperate with owners of land in the establishment of such measures as may be appropriate in the control of soil



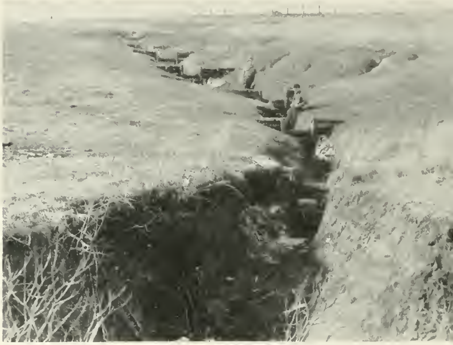
heet Erosion. Quantities of Top Soil have been Washed Off and Spread on a Neighboring Field *Photo. U.S.F.S.*



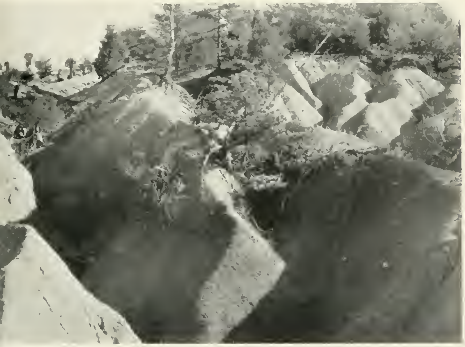
A Field on Which Erosion Is Controlled by Strip Cropping



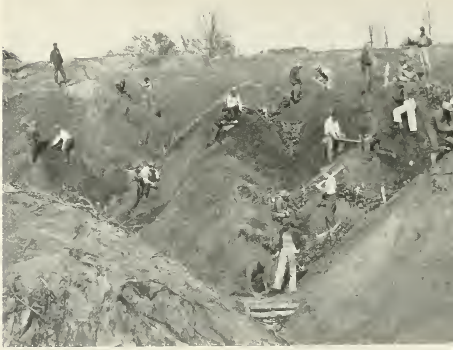
Cultivated Field Being Ruined by Gully Erosion



A Narrow Gully Controlled by a Series of Check Dams



Gully Erosion in Its Worst Form. Control is Necessary to Prevent Spread of Destruction and Retard Discharge of Silt



Control Measures: The Slopes Smoothed Off, Reduced in Grade, and Small Check-Dams Constructed. Workers Are Planting Locust Trees as a Further Control *Photo. U S.F.S*

EROSION

erosion; this cooperation to be carried out through the established agencies in states, and counties, or responsible land districts, or directly with owners. In preventive work to check sheet erosion, the field operations would be carried out by the owners or their agents, the public action being confined chiefly to aid in the organization of the work, and to providing special equipment and materials that may be beyond the means of the farmers. In case of serious gully erosion, a larger part of the labor may have to be assumed by public agencies. There should be a contribution from the states or other local sources of at least 50 percent of the cost of the cooperative work on the land, provided that a larger proportion may be expended where exceptionally serious conditions exist and the local interests are financially unable to contribute this proportion. The cost to the Government in carrying on the proposed program on an adequate scale may be as much as twenty million dollars annually during the next 20 years.

2. Strong emphasis on control of erosion in the general program of land acquisition for National and other public forests, and in connection with the withdrawal of marginal lands from agriculture.

3. Liberal appropriations by the Federal Government to continue and extend research, experiments, and demonstrations in erosion control, to make adequate surveys of the character and extent of erosion, and to cooperate with the states in classifying land as a basis for application of the cooperative program of erosion control.

4. State legislation authorizing cooperation with the Federal Government in a national program of erosion control, including appropriations to meet the conditions of federal cooperation and provide for the establishment of a responsible state agency to carry out the work.

5. State legislation authorizing the organization of conservancy districts for erosion control, with authority analagous to that of existing drainage, levee, or water districts.

6. Federal legislation enlarging and making more effective the control of erosion on lands owned by the government.

Coordination

The control of erosion is an essential feature in national planning for water use and control, agriculture, forestry, and grazing. A national policy of erosion control should be closely coordinated with the policies in these other fields of endeavor, and this coordination should extend to planning and execution of specific projects.

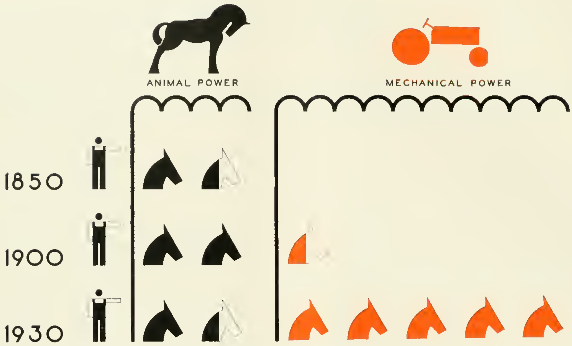
BOOK I PROBLEM

SECTION III

WATER IN RELATION TO LAND USE

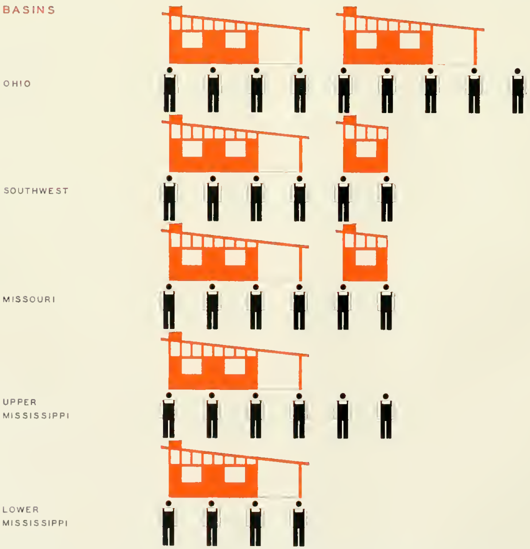
WATER AND FARM PRACTICE

POWER PER FARM WORKER IN U. S.

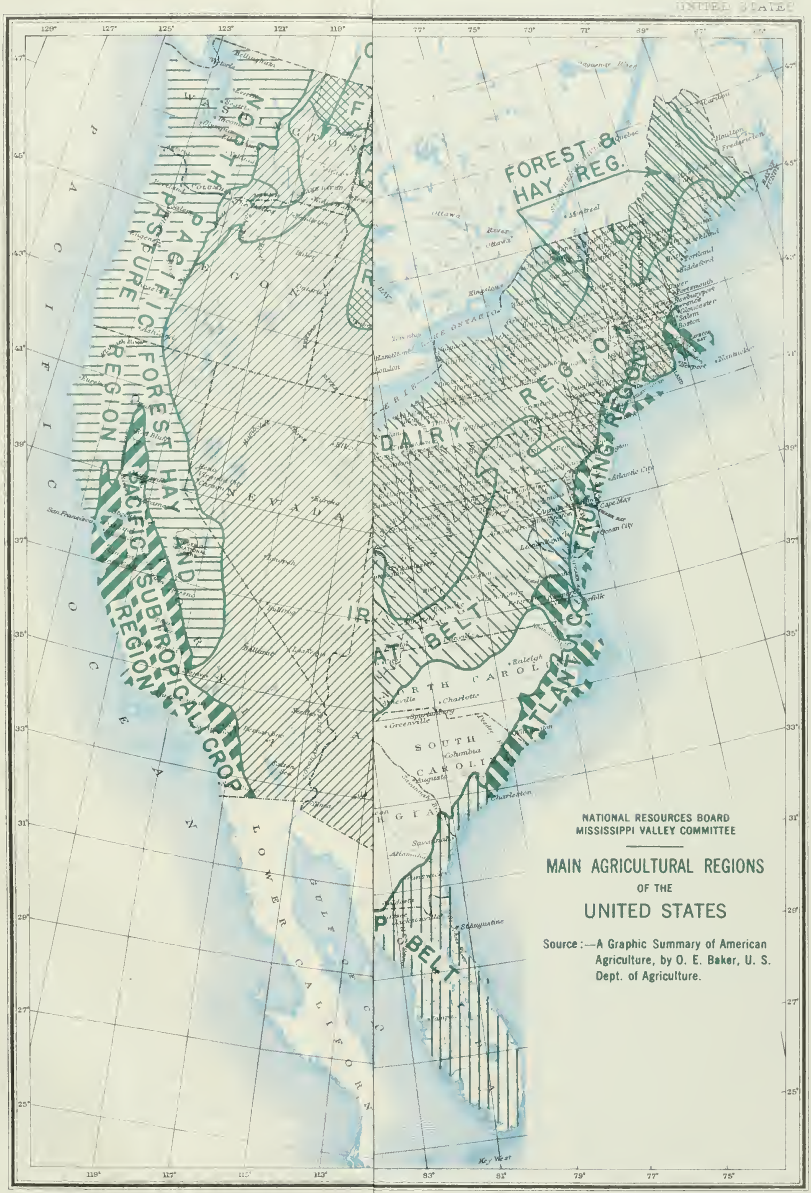


EACH COMPLETE SYMBOL = ONE HORSE POWER

FARMS AND FARM POPULATION



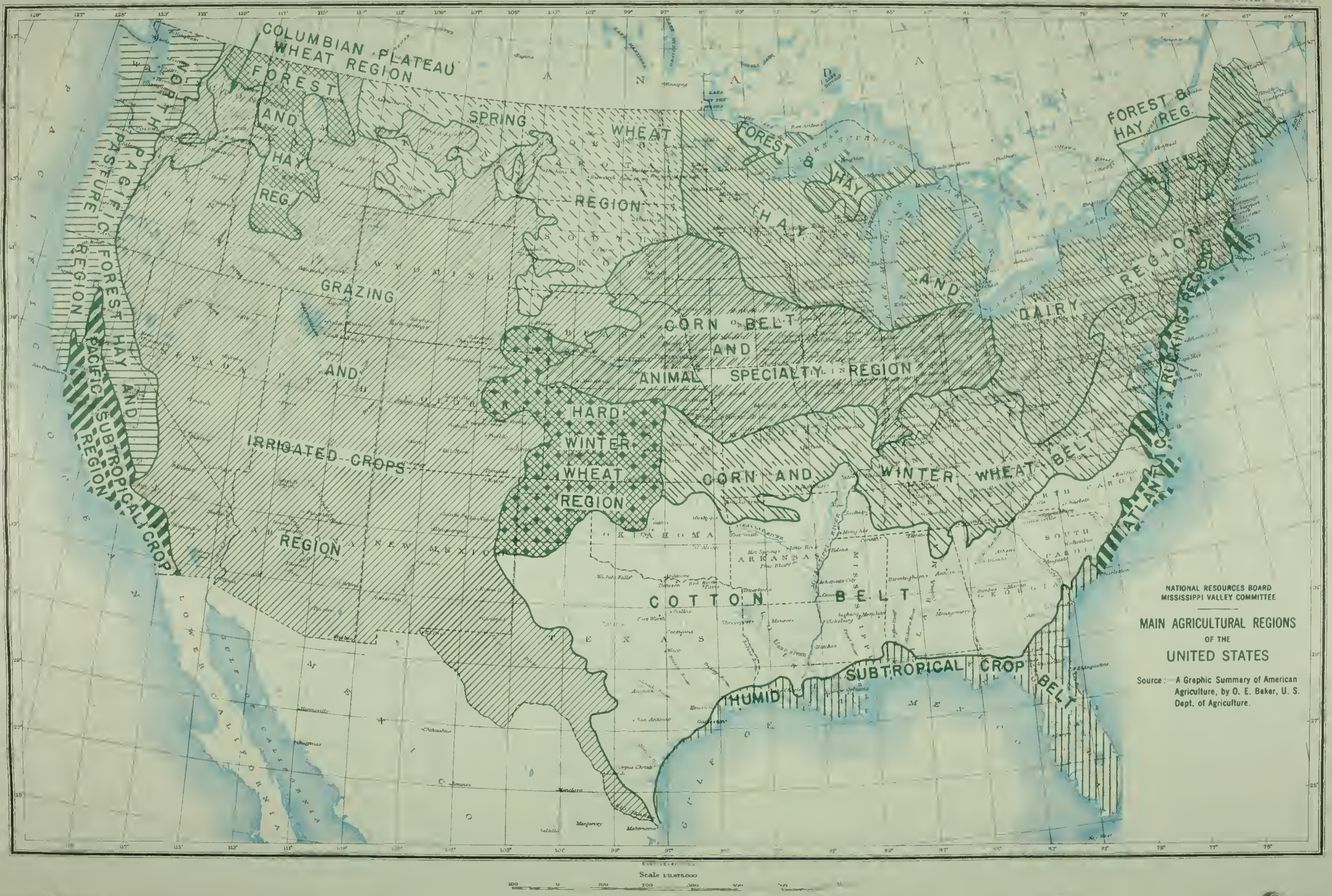
EACH COMPLETE SYMBOL = 500 000.



NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE

MAIN AGRICULTURAL REGIONS
OF THE
UNITED STATES

Source:—A Graphic Summary of American Agriculture, by O. E. Baker, U. S. Dept. of Agriculture.



NATIONAL RESOURCES BOARD
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MAIN AGRICULTURAL REGIONS
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Source: A Graphic Summary of American Agriculture, by O. E. Baker, U. S. Dept. of Agriculture.

Two factors of major importance in successful agriculture are preservation of the fertile top soil and availability of the requisite amount of water at the roots of growing crops. Both of these factors are profoundly affected by run-off and erosion, considered in the preceding section, and to a considerable extent by irrigation, to be considered later.

Both conservation of top soil and adequacy of ground moisture have been progressively affected unfavorably by the nature of the farm practice which has developed in the United States. Circumstances have favored a practice which involves relative increase of tilled crops and decrease of grass, hay, and similar crops. Tilling of the soil opens the way for escape of the precipitation as surface run-off and for water and wind erosion.

The early settlers on the eastern seaboard brought with them from England an agricultural practice which involved a rational proportioning of the lands of each farm between tilled and forage crops, and those who established the northern and central colonies found climatic and especially topographic conditions which made the standard English practice most suitable. Even today a New England tilled field is generally an island in a sea of grass and wooded lands. The use of animals for power as well as for food, and of wood for fuel as well as construction, made these pastures and wood lots important. Descendants of these early colonists as they moved westward to the Mississippi carried with them the practice of their fathers.

The settlers of the southern colonies found different climatic and somewhat different topographic conditions, and these conditions induced a different kind of agriculture and farm practice. Cotton and tobacco proved to be for them highly profitable cash crops which could be exchanged for manufactured commodities from the mother country. Therefore the individual plantation was not compelled to maintain the same degree of self-sufficiency as the northern farm. A trend toward exhausting cultivation of the better soils set in. When any particular land became too exhausted, cotton and tobacco cultivation moved to new areas. The assumed abundance of natural pastures and of wooded lands, and the apparent inexhaustible extent of territory awaiting settlement, delayed serious consideration of the ultimate consequences implicit in the trend toward a new agricultural practice of more extensive and more intensive clearing and tilling of the land.

The agricultural practice which caused serious erosion and loss of ground-surface moisture did not develop until the Mississippi Valley had been settled and brought into a world market by modernized transportation systems. Here climatic, soil, and especially topographic conditions—vast areas of flat, unwooded prairies and plains—favored grain crops which could be produced by a progressively mechanized agricultural technique. This led to relative increase of tilled and decrease of grass and hay acreage. The trend was intensified as automobiles and tractors were substituted for animals as a means of transportation and source of power. Pressure of population caused the more hilly lands, with greater susceptibility to run-off and erosion, to be included within the tilled acreage. The rectangular lay-out of counties, towns, and sections in the Mississippi Valley, and a corresponding location of highways, farm boundaries and even field fencing, induced a habit of plowing which has no regard for contours and actually increases the volume and effects of run-off and erosion. Finally, the eagerness to produce grain crops led to tiling of moderately wet, and to drainage of excessively wet lands, to a rushing of precipitation as quickly as possible to the rivers and the sea, and thus increased the area susceptible to water and wind erosion.

So serious today is the loss of topsoils and of ground-surface moisture that continuance of the present rate for another century would jeopardize the very existence of a self-sustaining agriculture in the United States.

This is the point where water problems and land-use problems overlap in a particularly vital manner. The Mississippi Valley Committee recommends to those institutions and to those agencies of the Federal and State governments primarily concerned with land use and agricultural practice, serious consideration of this vital problem. It is suggested that every unit of land in the United States should be inventoried as to its physical characteristics and best uses; and that there should be carried forward an educational campaign of allocation to use and of farm practice which will preserve for the generations to come this rich heritage of soils with which Nature has endowed the United States.

IRRIGATION

I. In Arid and Semiarid Regions

Necessity for Irrigation: In general, where the annual rainfall is less than 15 inches, profitable crops cannot be grown without irrigation. In the semiarid region, an irregular area comprising parts of Montana, North and South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, and Texas good crops are grown some years without irrigation, but, because of frequent disastrous droughts, crop failures are common unless water is available for irrigation. In the arid region farther west no important raising of crops is possible without it.

Water for irrigation is expensive, so it is desirable not to waste the water supply, that is, not to apply it oftener or in greater quantity than is needed. The application of irrigation water to crops is a laborious process, and therefore also expensive. It is impossible to tell exactly when a crop is about to suffer from lack of sufficient moisture, or what quantity it will be most economical to apply; but many careful observations and experiments combined with long experience have built up such a body of knowledge concerning the science and art of irrigation that it is probably as accurately known and as efficiently practiced as any other aspect of agriculture.

Extent of Irrigation: In this country irrigation is chiefly practiced in the West. Although it has been practiced for thousands of years in the warmer parts of Europe, Asia, and Africa, it is only during the last hundred years that it has become important here. At first, irrigating water was obtained by individuals, or small groups, who were able to find locations where they could convey it from streams to the adjacent fields through small and relatively inexpensive ditches. As all the easily obtained supplies became exhausted, in order to add to the irrigated area it became necessary to build bigger and more expensive canals, often many miles in length. This required some sort of corporate organization to provide the necessary financing and construction.

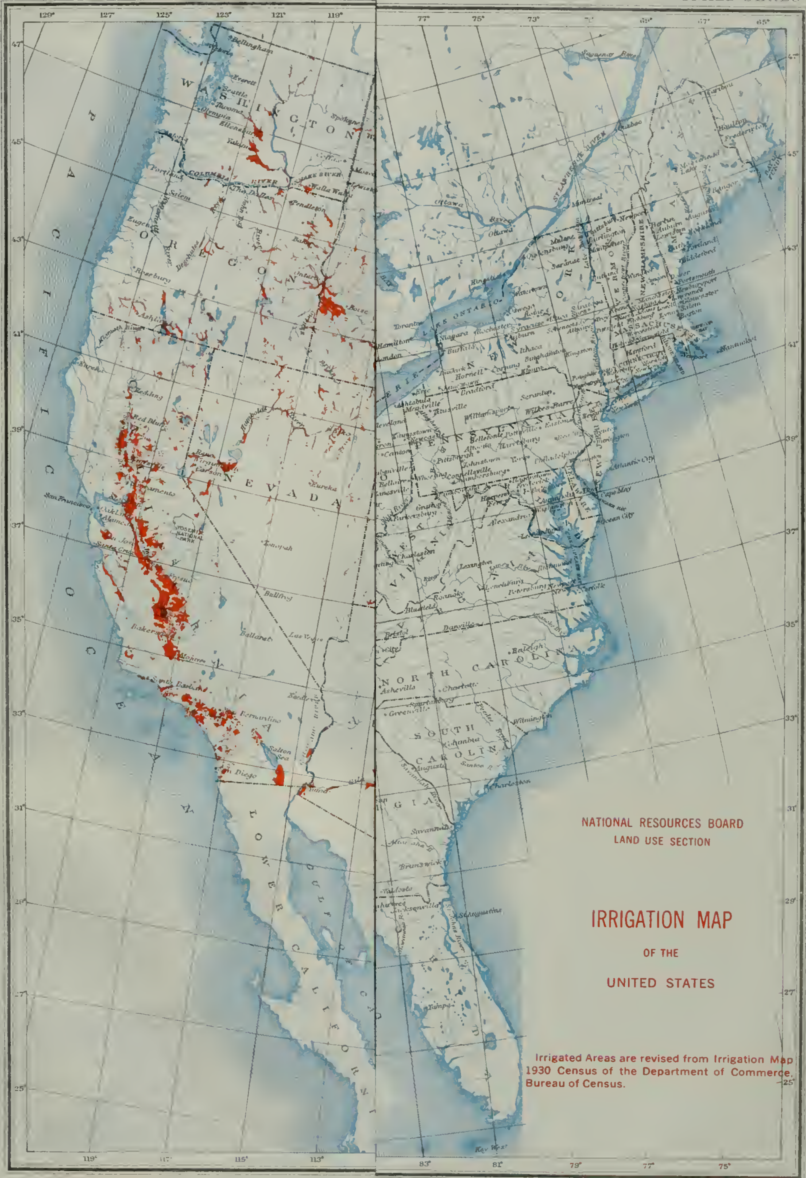
The passage of the Reclamation Act in 1902, which provides for the building of large reservoir and canal systems by the Federal Government and for the sale of water rights to settlers on easy terms, gave a tremendous impetus to irrigation development in the western states, including the further extension of private enterprises. In all, the Reclamation Bureau has built 52 storage dams. Every one of these is to improve the irrigation water supply of existing communities, and the Bureau of Reclamation's efforts are today directed mainly to the rescue of harassed and impoverished communities, that lack money and credit to help themselves.

In the 17 western states, the last census showed that out of 168 million acres of crops grown, 14 millions were irrigated. Of over 3 billion dollars value for all crops in those states, nearly one billion was the value of the irrigated crop.

Sources of Water Supply: The ultimate source of all water for irrigation is, of course, precipitation. The water is taken by the irrigators, individually or by community cooperation, usually from surface streams and lakes, but sometimes from underground supplies. More than two-thirds of the area irrigated, according to the 1930 census, was supplied by gravity flow from streams, somewhere near one-tenth by pumping from streams and lakes, and more than one-tenth by pumping from wells. Pumping from streams and lakes is the common means of getting irrigation water in the Gulf States, and pumping from wells is the common method in Arkansas and Eastern States. The chief reason for the prevalence of pumping for irrigation in the humid region is that such plants are nearly always for individual farms, and it is rarely feasible to provide a gravity supply of water on the land to be irrigated. In parts of Florida, flowing wells are common.

In pumping from wells, if the annual withdrawal of water exceeds the annual replenishment of the ground-water supply, there is a progressive depletion of that supply, which proceeds to the point of exhaustion, or develops pumping lifts so great as to increase the cost of water beyond economic limits. In some situations it is practicable to replenish the ground-water supply by artificial means, such as the water spreading which has attained material vogue in the West.

Water Requirements: The amount of water required for irrigation depends on the crop, the soil, the rainfall, and other climatic conditions. For example, forage crops generally require more water than vegetables or small grain; whereas corn, sorghum, and beans need less than vegetables or small grain. Sandy soils generally require more water than clay soils, because more is lost to the lower soil out of reach of the plant roots. Irrigation is necessary only to supply to the crops the amount that rainfall does not provide when needed.

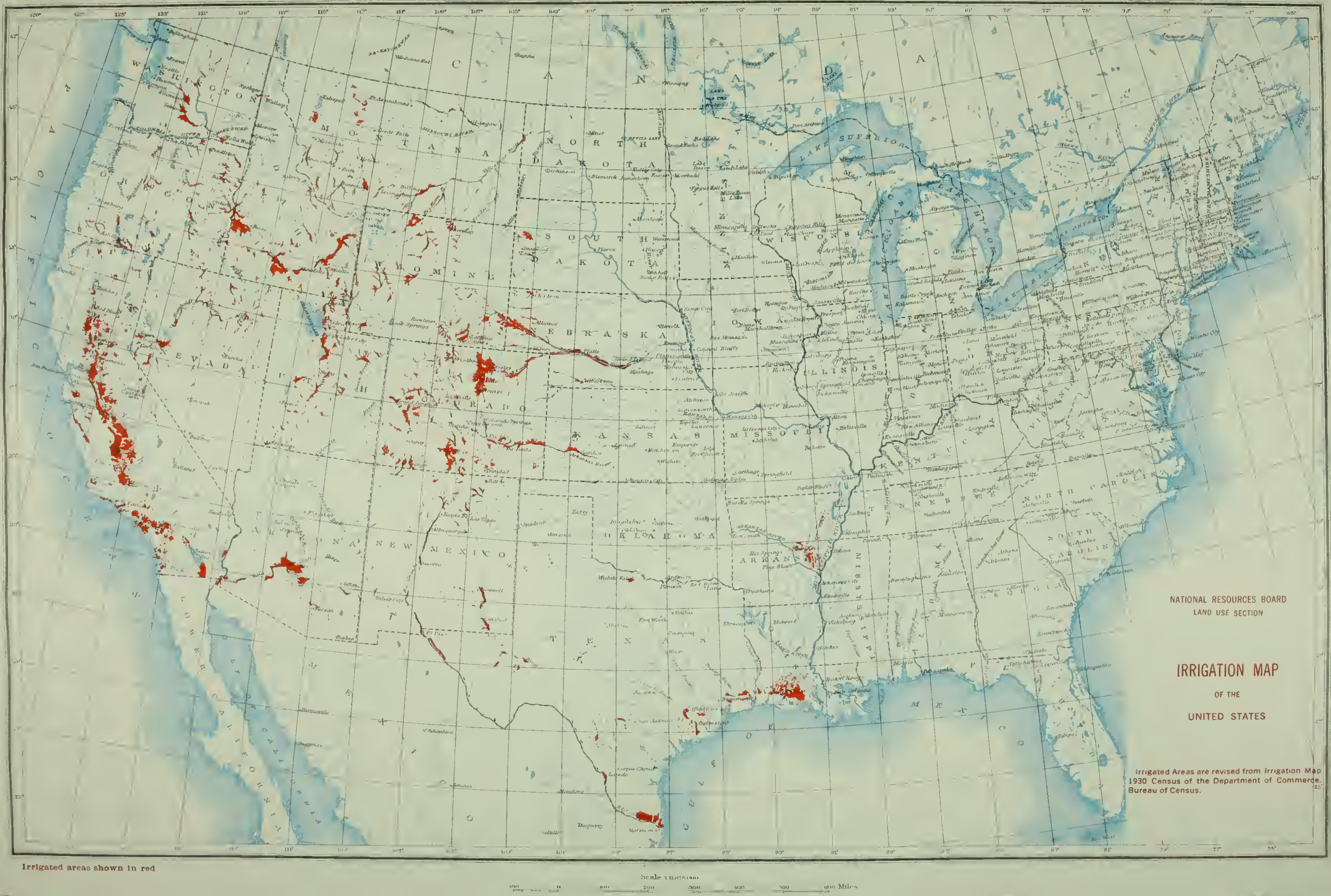


NATIONAL RESOURCES BOARD
LAND USE SECTION

IRRIGATION MAP
OF THE
UNITED STATES

Irrigated Areas are revised from Irrigation Map 1930 Census of the Department of Commerce, Bureau of Census.

Irrigated areas shown in red



NATIONAL RESOURCES BOARD
LAND USE SECTION

IRRIGATION MAP
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Irrigated Areas are revised from Irrigation Map 1930 Census of the Department of Commerce, Bureau of Census.

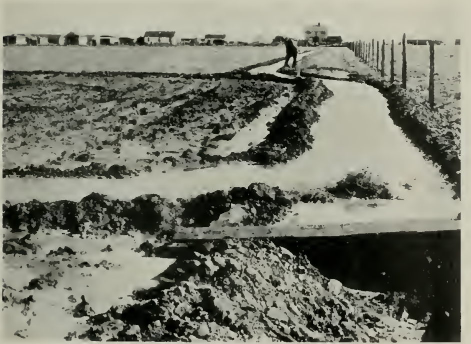
Irrigated areas shown in red

Irrigation Water Supply from a Flowing Well *B. of R. Photo.*

Orchard Under Irrigation—Fruit Is a Profitable Cash Crop on a Number of Projects *B. of R. Photo.*

Irrigation by the Flooding Method *B. of R. Photo.*

Once a Sage-Brush Desert, Irrigation Has Reclaimed This Area for Productive Use


Irrigation Supply Carried by Ditches *B. of R. Photo.*

Irrigation Applied to a Cultivated Crop. *B. of R. Photo.*

IRRIGATION

The average seasonal irrigation requirements for different parts of the West have been shown by extended studies to range from 0.85 to 3.1 acre-feet per acre—that is, the equivalent of from 0.85 to 3.1 feet depth upon the land irrigated. East of the Rocky Mountains the seasonal requirement ranges from 1.2 to 2.3 acre-feet per acre under the usual cropping practices. These are the amounts required in addition to the normal rainfall in the different localities.

Irrigation Laws: In many parts of the arid region, and in some parts of the semiarid regions, the water available is insufficient to irrigate the lands, in consequence of which conflicting claims to water rights have been a source of much litigation. In those regions State laws recognize the doctrine of beneficial use, which prohibits any one acquiring a right to water and holding it without actually using the water. The laws also recognize the doctrine of priority, which means briefly that "the first in time is the first in right". Some western states also recognize riparian rights. A riparian right is that right to use water from a stream which flows through or borders the land to which the right belongs and arises from the fact that the land borders the stream, not from appropriation or use. In the humid region the riparian-rights doctrine is virtually the only one recognized in State laws, and probably has served satisfactorily up to the present, because in that region conflicts over the use of water for irrigation have been rare. There have been indications recently, however, that scarcity of water may occur even in humid regions and that some of the laws relating to appropriation and use of water adopted by western states are applicable to conditions in the East.

The law recognizes, also, that certain uses of water are superior in right to other uses. This is a matter for consideration in connection with the coordination of the varied valuable uses of water, and is an important item in long-time planning for the use of river flow.

The evolution of land and water policies suited to the economic conditions created and modified by irrigation, is far from complete or satisfactory. Many of these policies which seem to be axiomatic are but past traditions and customs. Because the greater part of the land in the arid region can be used advantageously only for forestry or grazing, and because the amount of water available is relatively small, irrigation areas must always be comparatively small and widely separated. The total probably would be less than one percent of the cropped area of the whole country. The influence of the irrigated areas is, however, felt in many directions other than in supplying winter feed for range stock on the surrounding territory and adding value to the surrounding grazing land. The isolation of irrigated areas, inherent in this type of agriculture, requires peculiar and special land and water policies, and to a degree as yet only partly appreciated.

Irrigation Organization: About one-third of irrigated land is provided with water by the individual owners, or by partnership undertakings without formal organization, but the larger irrigation works are costly and require the organized cooperation of many farm owners. State laws in the West provide for several types of organization, the forms in most extensive use being (1) irrigation districts, which are public corporations and (2) cooperative or mutual enterprises, commonly of stock-company form with the stock owned by the water users. The cooperative enterprises embrace about one-third of the irrigated acreage, and the irrigation districts about half as much. Six percent of the acreage is supplied by water bought from commercial enterprises, incorporated or otherwise. The U.S. Bureau of Reclamation projects comprise nearly 10 percent of the irrigated lands.

Irrigation Finance: The investment in western irrigation works and water rights, as shown by the census for 1930, averaged $40 per acre of land that the works were capable of irrigating, the State averages ranging from $20 in Kansas to $89 in Arizona. For Arkansas and Louisiana the averages were $32 and $20, respectively. Cost of leveling and otherwise preparing the land for irrigation has averaged $28 per acre for the western states, rising to $57 per acre in Washington. By adding the average figures, the investment in irrigation improvements may be estimated, then, as about $68 per acre on the land benefited. Costs of maintenance and operation of the irrigation works averaged $2.77 per acre in 1929 for all enterprises, but for those where the water was all pumped from wells the average cost was $9.17.

Most of the capital to build the dams, canals, and other irrigation works has been supplied from private sources, although more than $200,000,000 had been spent to June 30, 1933, by the United States Bureau of Reclamation on 35 irrigation projects. The money for construction of non-Federal projects has been raised principally as follows: For irrigation districts, from the sale of bonds payable from the proceeds of taxes or assessments which are a lien on the land; for mutual irrigation companies, from the sale of capital stock to prospective water users and/or the sale of bonds secured by the irrigation works or by purchase contracts for land and water rights; for small cooperative enterprises, by contributions of capital and labor by prospective water users; for commercial enterprises, by the sale of capital stock and/or bonds of the promotion company.

Irrigation Problems: Most irrigation projects have been successful from the standpoint of land reclamation or improvement, but many of them had occasioned losses to investors in their securities even before the present depression.

Of the private enterprises, the greater number have been in difficulties at some stage of their development; and in the case of those financed by Federal appropriations, it has been necessary several times to postpone repayment of the construction charges and to spread the payment over a greater number of years than was originally intended.

Among the causes for the default of so many irrigation enterprises may be mentioned: inadequacy of the water supply; inadequacy of the irrigation system to serve all the land charged with the cost of construction; inability of the farmers to meet the high charges out of the proceeds from their crops; exploitation and speculation in providing water and land; inclusion in the project of low-producing land; water logging and accumulation of alkali in the soil caused by waste water from irrigation; graft and bad management. In spite of the financial difficulties, however, comparatively little land once reclaimed and irrigated has ever been abandoned and allowed to return to a desert condition.

Governmental Assistance: In addition to the promotion of irrigation by the Federal Government, the States of Utah, California, Nebraska, Washington, Oregon, and Wyoming have extended aid to irrigation districts from time to time.

Oregon guaranteed the first five years' interest on irrigation district bonds, while the other states authorized the investment of state funds in bonds of districts. By the end of 1928 Oregon had advanced money for the payment of interest on $9,384,000 of bonds of 15 irrigation districts. Three-fourths of the bonds on which the state contracted to advance interest were in default in 1929. In 1930 Oregon repealed the provision in its constitution which provided for guaranteeing interest on irrigation district bonds.

The other four states invested public funds amounting to more than $2,500,000 in irrigation district bonds. Two motives governed the purchase of irrigation bonds: investment and development. When the chief motive was investment, the bonds were selected from the standpoint of security; if development as well as security was desired, the funds were placed where it was believed they would do the most good in developing the agricultural resources.

The effect of such state investments, or of the authorization for making them, probably was to improve, more or less, the market standing of the bonds of irrigation districts in these states.

Water Power and Irrigation: When Federal reclamation began, the opportunities to generate hydroelectric power as an adjunct to irrigation were not appreciated and were ignored in reclamation laws. Now it is realized that power generation is an important factor. The revenue from several of the power plants already built by the Bureau of Reclamation is greater than the income from irrigation payments, thus making possible many irrigation works, which, without it, would not yet be feasible. The Government could not have built Boulder Dam had it not been that contracts for the power to be generated there insure the payment in 50 years of all the money required for construction, with 4 percent interest, provide subsidies to the States of Nevada and Arizona, and will finally leave $66,000,000 profit to be used in other developments. The remarkable increase in the return from power plants, and the industrial and social advantages of having hydroelectric power on irrigation projects, make water-power an exceedingly important factor for future activities.

Profits from Irrigation: Does irrigation pay? The answer to that question should determine whether irrigation is to be promoted or maintained.

From the standpoint of the farmer, irrigation should increase his net return or be abandoned.

Returns from irrigation farming in certain projects in the Arkansas and Missouri River drainage area, as found by agents of the Bureau of Agricultural Engineering and Bureau of

Agricultural Economics in 1924-25, are shown in the following table:

Returns from Irrigation Farming

Area	Cost of farm land including water, per acre	Average size of farm	Average excess of receipts over expenditures	
			Per farm	Per acre
	Dollars	*Acres*	*Dollars*	*Dollars*
Larimer County, Colo	130	92	998	10.80
Platte County, Wyo	77	186	661	3.60
Julesburg irrigation district, Colo	82	215	2,528	11.80
Boulder County, Colo	108	86	517	6.00
Weld County, Colo	110	123	1,490	12.10
Dawson County, Nebr	67	182	1,520	8.35
Logan County, Colo	[1] 30	259	1,195	4.61
Henrylyn irrigation district, Colo	48	167	1,097	6.56

[1] Only about half the land is under irrigation.

To pay interest on investment, depreciation on farm property and equipment, and wages for labor performed by the farmer and his family, the cash income of the average farmers on those projects ranged down from only $12.10 per acre to $3.60 per acre. On two of these projects the return was less than 6 percent interest on the investment, with nothing deducted for depreciation nor for wages for the family. (The data relate only to owner-operated farms.)

Most irrigation projects were undertaken in times more prosperous than the present, under conditions of maintained expansion and high prices that obtained for years and that were generally expected to continue. Now, with low prices for farm products, it is in many instances impossible to pay off the debts assumed in an era of high prices, and a great number of irrigation enterprises are in default.

Present Trends: In the West the present trend in irrigation is to improve conditions on existing systems rather than to attempt to reclaim new areas. Virtually the only new development is that undertaken by the United States Bureau of Reclamation. In some instances, systems that have an inadequate water supply are endeavoring to obtain additional water. Sometimes this is effected by combining with other enterprises having similar problems for the construction of supplemental works. For instance, the storage reservoir built recently by the Bureau of Reclamation on Snake River at American Falls, Idaho, provides storage water for several large irrigation systems in that State which frequently had experienced water shortage. The Bureau of Reclamation is also building a storage reservoir on the Owyhee River, Oregon, to provide a dependable water supply for several thousand acres hitherto dependent for irrigation water on the erratic flow of the river, and for several thousand acres more, which have been supplied with water pumped from Snake River at great cost. In addition this reservoir will supply water for the reclamation of new land.

Governmental participation in the cost of irrigation development has been limited, in the United States, mainly to the projects of the United States Bureau of Reclamation. Those developments were undertaken with the expectation that the costs of the works constructed would be repaid by the lands irrigated. The Governmental contribution of administration costs and interest on construction costs could be justified only on the ground of national indirect benefits to result from productive, populated land.

Future Policies: In order that irrigation shall be profitable to the farmer, it must repay the permanent investment involved, the expenditures for upkeep and operation, and wages for the additional labor of the farmer and his family in getting the water to the crops. That this has not been possible on many enterprises is attested by the great number of farmers who have abandoned the attempt, each leaving behind a considerable investment of labor and money for the benefit of the next comer, who would have his own resources to add to the value the prior occupant had perforce abandoned. Even on some of the Federal projects, it has been necessary to cancel parts of payments assessed to pay the costs, the Government assuming those losses. In future developments there should not be ground for saying anything similar to what has been said in some irrigated sections, that "It takes three crops of farmers to pay for an irrigated farm."

Under present conditions of agricultural production, markets, and prices, there seems no need for the nation to promote irrigation or other kind of development to increase the land in cultivation. This does not preclude a study of what and when development should be undertaken. In fact, present conditions rather emphasize the wisdom of taking stock of our national resources, and planning the ultimate best use of them. Neither is the present abundance of crop land a valid argument against protecting investments in irrigation works and irrigation farms from deterioration and loss.

In the promotional reports upon proposed large irrigation projects, too generally the costs have been underestimated and the profits from farming overestimated. In future studies the construction and development costs should be calculated more accurately, the possibilities of the lands be determined more carefully, and the returns to irrigators be estimated more conservatively.

II. In the Humid Region

The study of rivers as a source of improved power, navigation, and water supply has so largely monopolized the public attention that there is danger of overlooking the aggregate possibilities of a large number of individual farm projects for supplemental irrigation, particularly for use in years of deficient rainfall during the crop-growing period. Data collected by the U.S. Department of Agriculture[1] show that during the past few years, due primarily to drought conditions, there has been a considerable increase in irrigation activities in the humid section of the United States, particularly of citrus fruits in Florida and potatoes in Michigan. The Michigan State College has received thousands of inquiries from farmers for information on this subject within the past four years.

The present trend in humid irrigation is toward installation of irrigation as insurance against drought. With the present low prices of farm products, growers seem to feel that it is more important than formerly to protect their expenditure in plowing, seeding, cultivating, and fertilizing by controlling every factor that can help to guarantee a return for the money and effort expended.

In almost every way the problem of irrigation in the humid region is different from that in the arid. The prime difficulty is a lack of an accurate advance determination of the profits which may reasonably be expected to follow installation of irrigation equipment. In this region irrigation is not absolutely necessary. The farmers ordinarily obtain some kind of a crop every season, a crop which may not pay a profit, but which generally yields some income.

Formerly such irrigation was limited largely to the more valuable truck crops and high grade fruits, because it was not commercially applicable to large areas or to general farming, but within the last three or four years some of the less valuable crops, which might be classed as semitruck crops, such as potatoes, ear corn, and melons, have been irrigated.

Irrigation in the humid section is usually confined to small tracts over widely scattered areas. The individual projects range in size from one or two acres up to 250 acres or more, the average not exceeding eight or ten acres.

It is estimated that the amounts by localities are approximately as follows:

	Acres
New England States and New York	5, 000
Florida	25, 000
Other Atlantic seaboard states	8, 000
North Central states	6, 000
Arkansas and Louisiana	550, 000
Eastern Texas	110, 000
Other states	1, 000

The irrigation of rice accounts for virtually all of the above acreage estimated for Arkansas, Louisiana, and eastern Texas. The irrigation of cranberries accounts for about half the acreage estimated for the New England States and New York, and about one-fourth of that estimated for the other Atlantic seaboard states.

These data show also that, in scattered but still numerous instances of individual farm irrigation in the humid states, usually to the extent of a few acres only, water is applied by western methods, including flood, furrow, and border irrigation. All western methods of applying water require special preparation of the ground and careful attention during application.

In addition to the western open-ditch method of water distribution, water, pumped from a lake or river, may be distributed by hose lines or piping with flexible joints. The porous hose method of applying water for irrigating potatoes was developed in Michigan during the drought seasons of 1929 and 1930, and greatly simplifies the operation. This method does not require special preparation of the land, involves little labor, and is relatively rapid. The water can be applied to land that is not level, and, as now practiced, can be distributed to a distance of 750 feet from the source of supply. This distance can be increased by using feeder lines or larger hose. A pressure of 12 to 14 lbs. per square inch in excess of static and friction head is required, so that power becomes an important item.

Power Supply: Farm tractor engines, belted to cheap centrifugal pumps, are often used. Although the investment cost is low, the cost of power is relatively high, since these units do not have a high efficiency. Water can be applied by this method at night, during off-peak hours, which would have the additional advantage of reducing the loss by direct evaporation. The use of gasoline engines for power has often been necessary because of lack of available electrical energy. With future extension of rural electric lines and attractive power rates, especially for off-peak power, such as one cent or less for a night pumping load, the power cost would be materially reduced.

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[1] In particular, a letter from R. G. Tugwell, Acting Secretary of Agriculture, June 23, 1934.

The cost of potato irrigation in Michigan by this method as now practiced ranges from $1.75 to $2.75 per acre-inch, including labor, overhead expense, and power.

Profits From Irrigation: Irrigation installations are expensive. They often cost as much as the land they water and sometimes much more, but instances have occurred where one year's increase in crop value has paid the entire capital cost of the outfit. Data collected in Michigan show that the increase in yield of potatoes due to irrigation ranges from 50 to 150 bushels per acre. An apple orchard in Ohio in 1932 yielded 290 bushels per acre on non-irrigated land and 360 bushels on irrigated land. The irrigated orchard returned $90 per acre above the cost of irrigation. A field of irrigated potatoes in New Jersey in 1933 yielded 270 bushels compared with 146 bushels on an unirrigated field. In 1932 an apple orchard in Georgia yielded $4 per tree more than unirrigated apples. An 80-acre field of alfalfa in Virginia, for which irrigation was provided at a cost of $1,200, is reported to have returned $2,400 from one cutting. The owner of a 60-acre apple orchard in Virginia estimated that the increased yield in one year was worth more than the cost of the irrigation system.

Against these isolated examples showing what has happened under very favorable conditions may be set numerous cases in which the increased yield obtained by irrigation has not been sufficient to justify the investment. In many cases an owner has considered the benefits of irrigation not sufficient to pay the running expenses and upkeep and has abandoned the plant.

Water Supply: The water supply may be derived from: (a) natural lakes, ponds, or perennial streams, in which case no artificial storage is required; (b) spring run-off from the small drainage areas of intermittent streams—in this case the entire supply to be used must be impounded; (c) wells, where storage may also be required, if the well's rate of yield is insufficient to provide water at the rate required during the irrigation period. Of these, (a) and (c) are the most promising sources of supply. There are, however, large areas in the humid and semi-arid portions of the United States where there are few lakes and only a limited ground-water supply, and where perennial streams are not sufficiently numerous to provide water except to relatively few farms. There exist, however, many small intermittent streams which go dry in the summer, but which yield considerable run-off in the spring. In many areas such streams are the most available source of water supply for supplemental irrigation on individual farms. This involves storage of the necessary supply, and means the saving of water that is otherwise entirely wasted, but it leads to certain difficulties.

The pond site must be examined to be sure that its bottom is reasonably impervious, otherwise it will be necessary to puddle or treat the bottom to avoid excessive seepage. Usually enough silting will occur to seal the pond after a few years' use. An excessive amount of silting is, of course, objectionable. Soil erosion control can be practiced on the individual property, but, unless the whole drainage area is controlled, silting may soon diminish the storage capacity to a serious extent.

The quantity of water required to supplement sub-normal rainfall in general crop production is from 6 to 12 inches in humid regions and 12 to 24 inches in less humid districts. To provide one acre-foot per acre or 12 inches depth of irrigation water for a farm containing 100 acres of growing crops requires a net supply of 4½ million cubic feet of water. This would require a reservoir of 10 acres area with an average depth of 10 feet and a maximum depth of, say, 15 feet. To these depths should be added at least 2 to 3 feet to allow for evaporation and seepage.

The dam necessary to impound this volume of water would entail a heavy expenditure. Abutments and aprons are expensive items and usually a relatively long and deep overflow section is required to provide for storms of the cloudburst type which are likely to occur in small drainage areas. Unless the dam is safe under such conditions there is danger of property damage downstream which the owner of the dam cannot afford to assume.

In spite of these difficulties there are many places where the necessary storage can be provided at reasonable cost. Many pond sites, in Minnesota for example, whose outlets have been lowered could have these outlets restored. Certain swamp lands heretofore drained might best be converted back into ponds. Detailed studies for the specific purpose of providing farm storage often reveal possibilities that ordinarily would not be recognized.

FORESTRY

The Forest Situation

The history of the American forests has been one of exploitation, depletion, and, on large areas, actual devastation. Very properly the forest was cleared for agriculture, home and town sites, transportation, and industrial purposes. The forests were so extensive that no heed was given to their replacement after cutting. As rapidly as one region was exhausted, the development of transportation and new devices in timber exploitation brought to the markets material from other regions. People looked upon the forest as inexhaustible. The old timber, it was thought, would last for many generations and nature in her great bounty would quickly reestablish the forests after cutting, for the distant future. Meantime forest fires increased in number and destructiveness, serving, by the end of the nineteenth century, to call attention to the urgent need of action to conserve the forests of the country.

Within the past generation great advances have been made in the establishment of public forests, in organized fire protection, and in general public interest in forestry. In spite of this good beginning there are still more than 160,000,000 acres of forest land without protection from fire; the old methods of exploitation, without provision for forest perpetuation, are still in use on the majority of the commercial forests of the country; we are still depleting our timber supplies more than twice as fast as production by growth; and the economic and social consequences of years of abuse of the forest resources are now being felt in many states and communities.

To solve the national problem, we must check further waste by destructive exploitation of our remaining timber, to bring under control the forest fires and infestations of insects and diseases, and to initiate on a wide scale the rehabilitation of the areas on which the forest has been greatly impaired in productiveness or has been destroyed. This can only be accomplished by a vigorous public policy in which the Federal Government must take the active leadership.

At the present time about 20 percent of the land surface within the Mississippi Basin is classed as forest. Prior to settlement, forests covered about 40 percent of the land. The largest percentage of forest is in the eastern portion of the Basin. West of the Great Plains the forest is chiefly confined to the higher elevations of the Rocky Mountains and outlying spurs, at the headwaters of the Missouri and Arkansas Rivers. Narrow ribbons of forest growth occur naturally along the water courses in the prairie region and, since settlement, many farmers have established windbreaks and small wood lots by planting.

Services from the Forests

Forest lands of the country represent a natural resource, comprising today about 600 million acres. Such an expanse provides many varied products and numerous public benefits of vital importance. The major services are as follows: They provide raw material for building construction and for the manufacture of many articles indispensable in everyday life; they support industrial activities and furnish employment on a very large scale; they occupy and provide a productive use for land which is unfit for agriculture and otherwise would be idle; they have locally a beneficial influence on atmospheric conditions; they are the most effective cover on slopes for the protection of soil from erosion; they retard the surface run-off of water; they play an important role in recreation and public health; and they provide a natural home for wildlife.

Forests and Erosion

The conservation of forests on the steep slopes in mountain areas and elsewhere is of special value in the control of soil erosion. The web of roots of trees and lesser growth in the forest penetrates the soil in all directions and holds it firmly in place. The canopy of branches and leaves checks the force of heavy rains. The ground cover of litter and humus protects the top soil from the wearing action of water running over the surface. The service of forests in checking soil erosion and in lessening run-off of water on slopes constitutes the chief basis for the policy of extending control by public ownership or otherwise on critically located land in mountain areas.

Forests and Run-off

Forests lessen the velocity and reduce the volume of the run-off of water on slopes. Some of the falling water is intercepted by the branches and leaves of the trees and evaporated before it can reach the ground. The trees, shrubs, and other vegetation and the ground litter act as a mechanical check to reduce the velocity of the surface flow of water. Of special importance is the power of the litter and humus to absorb and hold water. The litter maintains the soil in a maximum condition of porosity for infiltration of water,

A Virgin Forest at Left. The Forest Checks Erosion by Its Network of Roots and the Litter and Humus on the Ground. Vegetation and an Easily Infiltrated Soil Retards Run-off

Photo U.S.F.S.

A mountain stream bordered by steep slopes. The forest is of vital importance in checking erosion, retarding run-off, and lessening freshets.

and it protects the clogging of the pores by a mud film that develops on exposed soil. In the case of prolonged rains which cause large floods the litter and soil become saturated and the effect of the forest in reducing the volume of run-off is greatly lessened. Under certain circumstances the retardation of the melting of snow in the spring is an important factor in checking excessive run-off.

The effect of reducing the velocity and volume of surface run-off of water is to moderate freshets and ordinary floods which originate in wooded regions. While forests are important in lessening the severity of torrents and local floods, their influence is limited in case of great floods on our major river systems, which are the result of prolonged and heavy rainfall. Retardation of run-off and maintenance of the soil in a porous condition by forests on slopes increases seepage of water in the soil. In many circumstances there is a net increase of seepage water over that utilized by the forest vegetation and that retained in the soil, which becomes available to supply springs and to maintain the dry-weather flow of streams.

Failure of Private Ownership

Four-fifths of the productive forest land of the United States is privately owned. Of this about 60 percent is held by commercial owners, and the balance chiefly by farmers and other owners. Only a few owners of commercial timber lands have undertaken to adopt measures of forestry in the management of their properties, other than to cooperate with public agencies in protection from forest fires. The long time required to produce timber of value, the hazards from fire, insects, tree diseases, and other adverse agencies, uncertainties of markets, inequities and burdens of the prevailing tax systems, the relatively low prospective returns from forestry, in contrast to other forms of business ventures, have conspired to prevent any considerable number of private owners from embarking on forestry as a business undertaking.

The lumber and logging industries have been built on the system of exploitation of timber already grown. When the timber is exploited, the forest is depleted or wrecked so far as any immediate service is concerned, and often there is left a train of economic and social injuries to the community which was built up by the industrial activities furnished by the temporary lumber enterprise.

Greater progress has been made in the use of forestry methods by farmers, owners of private estates and recreation preserves and other non-commercial owners. The aggregate area of land held by such owners that is actually under good forest management is, however, relatively small. There has been a break-down of private ownership of forests, from the standpoint of their maintenance in productive condition. Not only has there been a failure on the part of commercial owners to undertake practicable forestry measures, but the situation has been aggravated in recent years by the unsound condition of the lumber industry itself, due to overdevelopment of manufacturing plants, cut-throat competition, and overproduction of lumber. There have been the inevitable consequences of interrupted employment, tax delinquency, many failures, wasteful logging, and local community distress. One expression of the situation is the very large area of land that is tax delinquent, a large portion of which is unlikely to be redeemed.

The benefits of forests in checking erosion and retarding the waters carried into streams will be secured by the widespread protection and constructive management of forests on the slopes of hills and mountains. A national policy of forestry should emphasize the control of erosion and of the run-off of water as one of its primary purposes.

A National Policy

The effort to develop a national policy of forestry which would bring about a better handling of the forests throughout the country has been under way for nearly a generation. A good begnning has been made, but there is needed a much larger participation of the public in the problem than has heretofore been undertaken. A national policy of forestry includes two major features; first, the ownership by the public of very extensive areas of land; and, second, public cooperation with private owners.

Public Forests: The National Forests, which were established on lands within the Public Domain, marked the real beginning of forestry on a substantial scale in the United States. The first reserves were set aside soon after the passage by Congress of the enabling act in 1891. In 1911 authority was granted by Congress for the acquisition of forest lands by purchase. The entire system now embraces an aggregate area of about 165 million acres, including 20 million acres in Alaska. Thirty-one states have now adopted a policy of creating state forests, and there are small public forests in a considerable number of counties and towns. The total area of state, county, and town forests now amounts to about 11 million acres. The foregoing does not include the National and

State Parks and the woodland parks of other public agencies.

It has become increasingly evident that it will be necessary for the public to take over a very much larger area of forest land if the public interests inherent in forests are to be safeguarded. The U.S. Forest Service has recently completed a comprehensive survey of the situation and reached the conclusion that there should be added to the areas now owned by the public about 225 million acres. Of this it is estimated that about 60 percent should be acquired by the Federal Government and about 40 percent by the states and minor units of government.

Other Features: It has been a consistent principle that the public has a responsibility in forestry beyond the acquisition and management of public forests. It is incumbent on the federal and state governments to take such action as may be necessary to prevent destructive practices on private lands which will lead directly or indirectly to public injury. The Government has already embarked on a plan of giving aid to states in bringing about a better protection and handling of private forests.

The major lines of endeavor in public forestry in addition to those involved in the acquisition and management of public forests are: (1) cooperative protection from fire on private and state lands; (2) cooperative protection of forests from insects and diseases; (3) establishment of equitable systems of taxation in the several states; (4) cooperation with farmers through extension teaching and by furnishing planting stock; (5) extension work with industrial and other owners, as well as with farmers; (6) a program of extensive planting, under the auspices of the Federal Government, of wind breaks in the central western states; (7) extensive work in erosion control; (8) research and experiment, a large part of which will fall on the Federal Government; (9) public credit, to aid owners who handle their lands on the principles of sustained yield; (10) an economic forest survey, to carry forward the work already initiated in the determination of the amount of standing timber, the condition of the forests, and the economic problems in the different regions of the country.

The Federal Government has a part to play in all of the foregoing activities. In most cases there is already basic authority for the work, but inadequate financial support. The Forest Service in the National Plan of American Forestry, recently published, estimates that in order to meet the urgent public needs of forestry there would be required in federal expenditures during the next 20 years, an average of about 47 million dollars per annum for acquisition of forest land and for other capital expenditures, and an average of about 27 million dollars per annum for maintenance of the National Forests, for cooperative work, for research and other current activities.

Forestry Under the Code

The code of the lumber and timber products industries contains provision for the introduction of measures of forest practice essential to the conservation and sustained production of forest resources. Rules and regulations have been formulated and regional boards and committees organized. It remains to be seen how effective this plan will be in bringing about a modification of the destructive practices heretofore in effect. The weakness of the plan is that it is a feature of a temporary recovery undertaking, and it does not provide adequately for enforcement of the forestry regulations by the Government.

Regulation of Private Forests

Numerous regulatory measures affecting the handling of private forests are now in existence. These are chiefly concerned with the prevention and control of forest fires. Two states have regulations requiring owners to leave seed trees under certain conditions in order to insure a reestablishment of growth of valuable trees. Otherwise, there have been no attempts to control methods of cutting in order to prevent forest destruction and consequent injuries to public interests. If the public undertakes a policy of cooperation with private owners of the character and scope that has been recommended, there must be assurance that private owners will do their part in adopting constructive measures of forest practice. Without public control such assurance cannot be given. The present lumber code of the N.R.A., if continued in some permanent form, offers the opportunity for a better ordered and more prosperous industry, and also for the application of systematic forestry on private lands, with such regulatory control by the Government as may be necessary to safeguard the public interests.

Coordination

Forests have an important part to play in erosion control, in protecting the slopes on drainage areas, in the problems of agriculture, in recreation, and the conservation of wild-life. National planning in forestry should go hand in hand with planning in these other fields.

CONSERVATION OF WILDLIFE

Importance of the Resource

There are many public benefits derived from an abundant supply of useful wildlife. It attracts people to country districts for recreation, for hunting and fishing, or to study the habits of wild creatures. Game and fish have a large value for food and other products. The protection of insectiverous birds is vital in preventing damage to crops. And as a feature of recreation the existence of wildlife increases local employment and financial returns from tourists, fishermen, and hunters.

The conservation of wildlife is an important phase of planning for water use and control. First, a long-time program of public development of water resources will increase the number and improve the condition of lakes, ponds, marshes, and streams, which are an essential feature of the habitat of waterfowl, fish, and certain mammals; and second, an ample supply of wildlife is of direct value in the economic development of regions served by water improvements. Of special importance is the problem of conserving and increasing the national supply of migratory waterfowl and fresh-water fish.

For many years there has been a progressive decrease of most forms of useful wildlife. This is true of waterfowl; upland game birds; song, insectivorous, and ornamental birds; large game; fur-bearing animals; and fresh-water fish. The supply of certain species of useful and interesting wildlife has been exhausted in some sections of the country, and some species are so rare as to be of little more than scientific value. In the case of waterfowl the supply has been greatly depleted, the birds no longer visit some of the former areas of large concentration, certain species are rarely seen, and several are approaching extinction.

There are two outstanding causes of the decrease of wildlife. The first is the impairment or destruction of the natural habitat of the wild creatures. The second cause is the excessive killing for sport and for market. These causes are accentuated by uncontrolled predators and by diseases which are often devastating in their effect.

The expansion of settlement and land use have inevitably encroached on the natural breeding and feeding grounds of many types of wildlife. The occupancy of the open prairies and plains has driven the remnants of the larger game into the mountains and forest districts, and bird life in this region has been reduced to a relatively small proportion of the original stock. Clearing of forests for agriculture and pasture, lumbering, and repeated forest fires have materially changed the local conditions of food and environment for wild animals and birds. The use of waters in dry-land regions for irrigation and other purposes, the extensive draining of lakes, ponds, and marshes, the frequent destruction of the natural vegetative cover bordering on bodies of water, and the pollution of streams, harbors, and estuaries have destroyed many millions of acres of breeding and resting areas of migratory waterfowl.

These devastating changes in natural habitat have been accompanied by a ruthless exploitation of wildlife by hunters. In the case of water fowl, the recent great drought is not alone responsible for the present critical condition of the stock of birds. The supply had already been enormously depleted over a long period of years. Development of highways, extended use of the automobile and motor boat, invention and continued use of automatic arms, and, in the case of wild fowl, ingenious devices of baiting, have made our wildlife easy prey to the hunters. To this must be added the ineffectiveness of many of our state game laws, lax administration of law, the lack of adequate funds for the enforcement of the federal migratory bird law, and the widespread failure to recognize the basic principles of constructive wildlife management.

Conservation Policies

Early efforts in conservation of wildlife were through local game associations and scientific agencies and directed to education of sportsmen and the general public in the need of restrictive measures in hunting and fishing. There followed the establishment of game laws and administrative organizations by states. These laws prescribed seasons for hunting and fishing and limitations on the take. For the most part the administration of the laws was lax and ineffective and in many sections lacked public support. The chief defect of the system was, and largely still is, the effort to administer a living resource like wildlife through legislative regulations.

The second step in wildlife conservation was taken in connection with the establishment of public forests, parks, and reservations set aside primarily for game conservation. Wildlife is recognized as a valuable natural resource on these public properties, and every effort is made to conserve it, though there have been many handicaps due to trespass, lack of public support, lack of scientific information, and in same cases unintelligent administration.

In recent years there has been a great advance through research in knowledge of the life habits and requirements of wildlife. The knowledge of the environmental needs of game, their food and breeding habits, and their seasonal movements, has aided in furnishing a basis for their actual management. Hence the emphasis now given to substitution for the old rigid state laws of authority to the administrative officers to modify the regulations relative to the use of the increase of game in accordance with its local requirements.

The swing of sentiment toward saving game has sometimes resulted in unintelligent regulations detrimental to its welfare. Thus the demand for complete conservation or prohibition of all killing of the increase, has led, in certain instances, to over-stocking of areas with game and to extensive starvation and disease on account of lack of food. Such conditions have obtained with deer in the Kaibab plateau in Arizona and also in parts of the East, and there is danger of its repetition elsewhere.

The successful administration of our public reservations, betterment of state management in many sections, and a greatly improved public sentiment have already resulted in an increase of some valuable species of large game. The commendable work of national and state associations of sportsmen and others interested in wildlife conservation, of civic organizations, and of scientific and educational institutions, have played an important part in improving state laws, in advancing federal legislation, and stimulating intelligent public opinion. The admirable efforts of agencies interested in conservation of inland fisheries, through development of hatcheries and restocking of lakes and streams are resulting in the progressive restoration and increase of fish life. In spite of these efforts our wildlife generally is still decreasing at an alarming rate.

Of special importance in wild life conservation have been the Migratory-Bird Treaty with Canada and the various acts of Congress relating thereto, and the recent Duck Stamp Act, which together give authority to regulate the killing of waterfowl and other migratory birds and also authority to acquire lands for breeding and resting places for them. There is now a basis for an effective federal control of migratory waterfowl. There remains the necessity of providing adequate funds for the enforcement of the federal regulations and to restore and extend on large scale the marshes and ponds essential to maintain the stock of birds.

A Public Problem

Wildlife is in a real sense a public resource; it is not the private property of the owner of land on which at a given time it may happen to be. The states have the power to control its use, to regulate the amount that can be taken by individuals and the seasons of hunting and fishing, and to prohibit altogether the taking of specified kinds of wildlife. The responsibility for the protection and constructive management of wildlife thus rests primarily with the public itself. The private owner of land may, under the trespass laws, prohibit others from hunting on his land, but he is subject to state laws in hunting on his own property.

Control of migratory birds falls in a somewhat different category. Through a treaty with Canada and Federal legislation enacted to carry out the treaty, migratory birds come under jurisdiction of the Federal Government.

Private owners, though subject to public regulations, have a personal interest in conservation of wildlife on their land, for hunting, for food, for their own general enjoyment, or for leasing privileges to others. There is, therefore, a basis for cooperation between the public agencies, private land owners, sportsmen, and recreationists, in the conservation of wildlife.

Thus it is evident that the responsibility of conserving and building up wildlife rests with the states and the Federal Government. Each has its specific functions. The objectives of wildlife conservation will be accomplished, however, only through close coordination of the efforts of the Government, the several states, quasi-public agencies, and the private individuals who may have an interest in this valuable natural resource. National planning is essential, in which the Federal Government should take the leadership.

Essential Public Action

Federal Action: The report of the President's Committee on Wild Life Restoration, presented early in 1934, made specific recommendations for immediate action, with special reference to the acquisition by the Government, of extensive areas for breeding grounds and refuges for various types of wildlife, and recommendations for the coordination of the activities of federal agencies dealing with wildlife problems. These and other features of federal action that are desirable are:

1. A large program of acquisition by the Government of lands suitable for the restoration of wildlife in different parts of the country. The President's Committee recommends an immediate objective of four million acres for breeding and resting grounds for migratory water fowl and shore birds; five million acres for upland game; one million acres as breeding and nesting places of song, insectivorous and other birds that are becoming scarce; and two million acres for big game, fur bearers, and other mammals.

2. A stronger financial support of the wildlife conservation activities of the federal agencies charged with the administration of the National Forests, Parks, existing federal wildlife reservations, and the Public Domain.

3. Adequate financial support for the enforcement of the federal regulations promulgated under authority of the Migratory Bird Treaty Act.

4. Effective coordination of the efforts of all federal agencies dealing with wildlife, including cooperation in the development and use of public reservoirs, pools, lakes, ponds and marshes, to provide for protection of the breeding and resting places of migratory waterfowl, with adequate funds for this special work.

5. A greatly enlarged program of research in the life habits of wildlife and the practical methods of conservation.

6. Leadership in educational work directed to encouragement of effective state game laws and administration based on sound principles of wild life management.

7. Educational work, in cooperation with the states and otherwise, to develop a more intelligent understanding of the importance of wild life and of its special problems on the part of the general public.

8. Encouragement of private efforts in wildlife conservation.

9. Leadership in a vigorous program for suppressing diseases of wildlife and of reducing the injury by predators.

10. Liberal financial support of the program of conservation of inland fisheries.

State Action: The appropriate activities of the state wildlife agencies are in many instances similar to those indicated in the foregoing list as desirable by the Federal Government. In certain lines of endeavor the Government should act through or in cooperation with the states. The states have immediate jurisdiction over wildlife. Their first responsibility is in sound legislation in wildlife and in vigorous enforcement of the laws, such as are in effect in some of the states. A second feature of state policy should be to extend the number of wildlife reservations and refuges. The state is in a specially favorable situation to encourage and assist private owners to improve the environmental conditions for useful wildlife in their woodlands and fields, and to cooperate with those interested in game farming. In the control of disease attacking wildlife the states have an important function. There is a state responsibility in educating the general public in the problems of wildlife, and also in training a competent technical personnel for administration and research. Liberal appropriations are essential to enable the state agencies charged with wildlife administration to carry out their work effectively.

The counties and municipalities have also a part to play in wildlife conservation, on their publicly owned forests, parks, reservoirs, and streams, in cooperation with the states.

The activities of the Federal Government need not in any way conflict with those of the states. National planning provides for coordination of effort by the several units of government toward a common objective.

RECREATION

A reservoir constructed primarily for recreation. The land on its borders is fully developed with summer homes, a golf course, and other facilities.

The New Public Problem

In recent years there has been a new and unprecedented demand for public-recreation facilities. This is a natural result of population increase, especially in urban communities, the high tension of modern life, and the increase of leisure time. Additional factors are development of the automobile and construction of highways, and the progressive closing to general use of private forests, fields, lakes, and streams, in country districts, and the occupancy of open city lots formerly available for sports. Finally there is a new appreciation of the benefits of recreation among all classes. In recreation we are dealing with a great human problem that touches the needs of all persons. There are involved the public health of communities, child welfare, checking of juvenile delinquency, the efficiency of workers in every group, and public morale generally. From these standpoints alone the problem of recreation is public in character and national in scope.

Business enterprise has been quick to respond to widespread demand for recreation facilities and equipment wherever profit is possible. In cities there are theaters, concert and lecture halls, amusement parks and resorts, arenas, gymnasiums, skating rinks, dance halls, bowling alleys, pool rooms, cabarets, and the like. In rural sections where natural features of beauty and interest attract visitors, there are provided summer hotels, over-night camps, boarding houses, roadhouses, shooting and fishing camps, commercial boys' and girls' camps, hunting and shooting camps, golf links, boating equipment for hire, and facilities for winter sports. A large industry has been developed for manufacture of equipment for parks and playgrounds, and articles and materials for various sports. In some States, recreation has become one of the most important industries.

Public Responsibilities

Private enterprise furnishes the major part of facilities for recreation, measured in investment of capital and annual expenditures. From the social point of view there is a definite limitation to the service of private enterprise in meeting the recreation problem. This is particularly true of outdoor recreation. We may not expect private enterprise to provide open squares, city parks, and playgrounds in cities, nor large regional parks and forests, wilderness areas, nor public shooting and fishing grounds. Maintenance of the highway beauty, and preservation of areas of scenic, historic, and scientific interest, are also a public responsibility. Already this has been recognized in the public recreation movement, by establishment of national, state, county, and municipal parks and forest reservations, by recent development of parkways, planting of roadside trees, landscape work along the highways, acquirement of roadside strips of forests, and by the effort to abolish unsightly commercial signs and structures in rural sections of public roads.

The system of National Parks embraces more than six million acres of land in 15 States, in addition to areas set aside in Alaska and the Hawaiian Islands. National Forests comprise about 145 million acres in 34 States and 20 million acres in Alaska and a small area in Puerto Rico. There are 71 National Monuments in the United States. Thirty-seven States have State parks or forest preserves, or both aggregating more than six million acres. More than 530 cities having a population of over 5,000, in addition to many smaller cities and towns, have established municipal parks. And there are county parks in 20 States aggregating more than 108,000 acres. In addition to the foregoing there are numerous national and State wildlife reservations and refuges.

Water Use and Control

Water plays a major role in recreation. The seashore, lakes, ponds, rivers, streams, and waterfalls, are among the more important features which attract people to the country. Summer homes, hotels, and camps are built near them, and great numbers of people are attracted to use the waters for bathing, boating, and fishing and to enjoy the stimulus of their beauty and invigorating climate. The recreation programs of the more progressive cities include development of ponds, lagoons, and swimming pools. Some of the most popular municipal and State parks provide public bathing beaches on the shores of the ocean, rivers, and lakes.

Public works for water conservation and control will enlarge the opportunities for recreation in three ways:

1. The construction of storage reservoirs which are maintained at a reasonably uniform level will create new centers for recreation. This service will be particularly important in the central valleys of the Mississippi Basin where there is a lack of natural features suitable for public recreation.

2. The maintenance of the dry-weather flow of rivers will greatly increase the use of streams where low water often interferes with boating or where pollution prevents fish life and makes the rivers unpleasant for recreation use.

3. Reservoirs and pools in many cases are suited for breeding and resting places for wild fowl and thus aid in the problem of wildlife conservation.

Frequently the value of waters for recreation exceeds their value for other types of service. Thus popular sentiment in some instances prevents the development of natural lakes in public reservations for storage lest their recreation features be impaired by raising and lowering the water. There may thus be a conflict in use between recreation and other uses of water which calls for coordination of use where this is feasible.

Public Policies

Great advance has been made in planning for outdoor recreation. This is especially true in urban communities in connection with general city and regional planning. During the past ten to fifteen years the movement for national and State parks has assumed national significance. The National Conference on State Parks, established in 1921, President Coolidge's National Conference on Outdoor Recreation, organized in 1924, and the work of the National Recreation Association and many other civic agencies, have not only contributed to awaken widespread interest in the problems of recreation but have brought about a great deal of intelligent planning for public action.

Most of the activities of the Federal Government in recreation have been connected with development and administration of the National Parks, Monuments, National Forests, and Wild Life Reservations. The Wilderness Area is a new type of reservation and so far chiefly confined to specially designated portions of the National Parks and Forests. The popularity of public reservations has led to a demand for their extension and also for new types of Federal recreation grounds. Fear is now frequently expressed that the penetration of areas of natural beauty by highways may alter their wilderness character. Hence, there is a demand that still larger areas in the National Parks and Forests be retained in their primitive condition, and new wilderness areas established outside the present reservations, without highways and with access only by trail.

The National Parks were set aside originally to preserve in their natural condition areas of supreme beauty and grandeur or of exceptional historic or scientific interest. They soon attracted a very large number of persons to enjoyment of their scenic and other features. They render a great service in recreation, but their selection was not governed in the first instance by a policy of creating a system of national playgrounds. The purpose was rather to preserve and prevent impairment of areas of great national significance. Hence the National Park Service has consistently endeavored to maintain the highest standards in the selection of areas for National Parks, and to resist the popular demand for creation of parks by the Federal Government, which are below standard from the standpoint of their natural features and which are promoted chiefly to meet local recreation problems or to enable local communities to benefit commercially from the existence of Parks supported by the nation.

The National Forests are in large part located in the mountains and contain areas of great value in recreation. They now attract more than 30 million visitors each year. They were not created primarily for recreation, but like the National Parks, render a great public service in recreation.

The restriction of the National Parks to areas of supreme grandeur and interest has resulted in a demand for federal recreation areas possessing less significant natural features but of value as public recreation grounds because of their location with reference to use by large numbers of people. It has been suggested that such areas be given a special name in order not to lower the standards of the National Parks. A further proposal has been made that the Federal Government grant funds to the states to enable them to extend their systems of parks. The proposed large expansion of the program of the National Forests will in part meet these problems. If the Government, in its program of withdrawing marginal agricultural lands, acquires considerable relatively small areas suited to public recreation, which are not located so that they can be made a part of existing National Forests or Parks, it will be necessary to determine whether they should be organized as federal forests or recreation areas or wild life refuges, or placed in the hands of the states for administration and development.

There are many areas of the country today which lack any public recreation facilities for the people. These localities and the states in which they are located are in many cases financially unable to acquire and develop public parks and playgrounds. Hence the demand for aid from the federal Government is likely to increase.

The foregoing are some of the problems which indicate the need of a National policy of recreation.

Features of a National Policy

The major features of a national policy and program of recreation would include:

1. A comprehensive study of the problems of recreation in the country, including the location of areas containing natural features of special interest, the areas now well supplied or likely to be supplied with public recreation facilities, and the areas now lacking but needing such facilities.
2. The determination of the respective responsibilities of the Federal Government, states and other governmental units and of private interests in providing facilities for outdoor recreation.
3. The coordination of the policies and administration of recreation by the several Government bureaus in charge of the federal reservations.
4. The extension of the principles of wilderness areas.
5. The recognition of recreation as one of the public uses of lands acquired by the Federal Government, which are not appropriate for additions to National Forests or National Parks.
6. Authority by Congress for the acquisition of lands for additions to National Parks and for the creation of new National Parks if the areas are of proper standard.
7. More liberal appropriations for the development of recreation facilities in the National Parks and National Forests. There is special need of such development in the National Forests.

Coordination

Recreation is an important factor in water use and control, in forestry, in wildlife conservation, and in the problem of withdrawal from agriculture of marginal lands. The public policies and programs of recreation in these various fields should be closely coordinated with a central national policy of recreation.

BOOK II BACKGROUND

PRECIPITATION AND RUN-OFF

PRECIPITATION AND RUN-OFF
IN THE MISSISSIPPI VALLEY

Climatic Controls

Probably no region of comparable size or of equal importance to human activities has as great diversity of rainfall and run-off as the Mississippi Valley. The briefest description of these phenomena, to be understandable, must be predicated on a perspective of the major climatic controls. There are several major controls of climate.[1] Those affecting the Mississippi Valley are:

Latitude: The Mississippi Valley lies between the 29th and 49th parallels of latitude, a distance of 1,380 miles, although the greatest distance along any one meridian (north and south line) is 1,130 miles from the mouth of the Mississippi in Louisiana to its headwaters in Minnesota. Such variation in latitude is bound to produce climatic differences which alone will profoundly influence precipitation and run-off.

Land and Water: The Mississippi Valley, except for the southern fringe, is remote from any ocean and consequently presents a continental type of climate with relatively great seasonal fluctuations of temperature. Such areas are prone to be productive of unstable air currents, frequent thunderstorms and tornadoes. In general they are controlled as to precipitation by the occurrence of cyclonic storms crossing the continent.

The great water areas of the Gulf of Mexico and the Atlantic Ocean, especially the Gulf, constitute the initial source of large quantities of water vapor carried into the Mississippi Valley by prevailing winds.

Mountain Barriers: The Mississippi Valley is shut in by the Rocky Mountains on the west and the Appalachians on the east. The Rockies particularly exercise a major control over climate, greatly reducing the moisture in winds from the Pacific. If equivalent east-west barriers existed north of the Gulf of Mexico, the interior of the continent would be far more arid. The Appalachians, being relatively low mountains, on the normally leeward side of the Valley, exercise less effect in preventing southeast moisture-laden winds passing to the interior.

Altitude: Winds flowing from large water areas precipitate moisture as they are forced to rise with increasing altitude of land surfaces. This phenomenon is pronounced on the western slopes of the southern Appalachians and largely accounts for the relatively high precipitation in higher portions of the Ohio Basin.

Prevailing Winds: These form another important control of precipitation and run-off in the Mississippi Valley. Having an essentially continental climate, the land area of the Valley tends to become colder than the oceans and Gulf in Winter and warmer in Summer. Hence, air pressure over the continent's interior is, on the whole, higher in Winter and lower in Summer than over the water masses. Because winds incline outward from a high pressure and inward toward a lower pressure region, there is a general tendency (interrupted by cyclonic disturbances to be described later) for winds during Winter to move gradually out of the high-pressure area over the western part of the Valley toward the south, east, and southeast, displaced by cold and relatively dry air from Canada. This is shown on Figure 1a. As the winds in general, except for the Ohio Basin, flow southward, they become heated and the vapor capacity per unit volume is increased. Hence, we find everywhere, the least precipitation during the Winter except for relatively small areas in the Ohio and Tennessee Valleys and a narrow band along the Gulf coast.

Conversely, during the Summer, pressure over the continent interior is lower than over

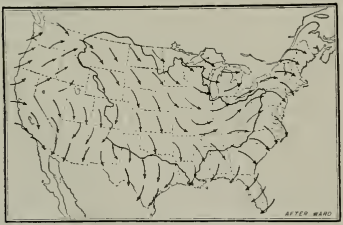

FIG 1A–PREVAILING WINDS IN JANUARY

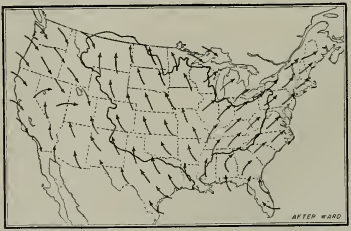

FIG 1B–PREVAILING WINDS IN JULY

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[1] "Major Controls of the Climates of the United States" by R. DeC Ward, Monthly Weather Review, October 1918; and "Climates of the United States" by R. DeC Ward, Ginn and Company, 1925.

the oceans, and there is a general tendency for winds to flow into the Valley. Because winds from the Atlantic and Pacific are cut off by mountain ranges, virtually the only gateway to the interior is from the Gulf. Hence warm winds which have passed over wide expanses of warm water enter the Valley and pass in a generally northward direction up the several river basins, as shown on Figure 1b. As these winds flow northward they become cooled by contact with land areas, by contact with colder air to the north, and by being forced to rise over mountain slopes or over masses of denser, cooler air, by which the temperature is reduced through expansion.

Storms: The Mississippi Valley lies in the path of the prevailing drift from the west of midlatitude air masses; therefore storms which cause disturbances in this air drift tend to move in a direction from west to east across the continent. These storms are more or less circular areas of low pressure called "cyclones", and are characterized by the following phenomena, as illustrated by the passage of a typical "low" over the Mississippi Valley shown on Figures 2, 2a and 2b, respectively:[2]

1. Entrance of low pressure area from Pacific on February 11. Pressure at center 29.65 Deg.
2. Movement eastward becoming central over Nebraska and Kansas on February 13, with increased intensity. Pressure at center 29.5 Deg.
3. Winds in general flowing toward and around the center in a counterclockwise direction.
4. To east of center winds from southeast. These winds come from warmer regions and may have blown over oceans. They contain much moisture and are chilled by blowing northward, by coming in contact with cooler air, and by being raised as they approach the center of the cyclonic area. Hence they precipitate their moisture. Therefore, the easterly quadrants of a cyclone of this type are likely to have the heaviest precipitation.
5. Northwest winds to the north and west of the cyclone bring cold dry air.
6. The cyclone has passed north of the Great Lakes by February 15, having pursued first an easterly and then a northeasterly course.
7. There is a precipitation area to the rear (westerly quadrants) of the cyclone due to cold air from the north flowing toward the center, which cools and raises the warm moisture-laden air from the south and east.
8. The cyclone is followed by an area of high pressure, called an anticyclone, usually bringing clear and cold weather.

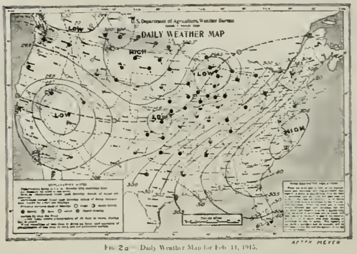

Fig. 2a — Daily Weather Map for Feb. 11, 1915. AFTER MEYER

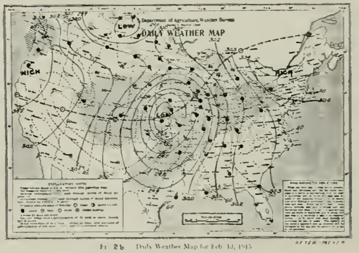

Fig. 2b — Daily Weather Map for Feb. 13, 1915 AFTER MEYER

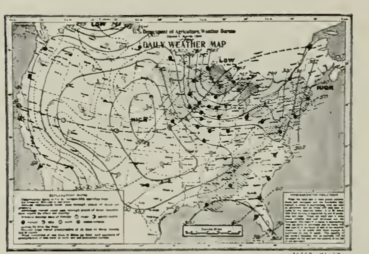

Fig. 2c — Daily Weather Map for Feb. 15, 1915 AFTER MEYER

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[2] Figures reproduced from "Elements of Hydrology" by Meyer. John Wiley and Sons, 1928.

The general tendency of cyclones to move in an easterly and then northeasterly direction is shown by Figures 3a and 3b, on which are indicated "storm tracks." These are mere generalizations of typical paths followed by large numbers of cyclones originating in the northwest and southwest.

Also bringing heavy occasional precipitation to the Ohio and particularly to the Tennessee Valley are the West Indian hurricanes which move up the east coast during the autumn, and occasionally pass a considerable distance inland. These account for much of the extremely high precipitation on the headwaters of the Ohio and Tennessee Valleys.

The control of winter climate of the Mississippi Valley is due chiefly to passage of cyclonic areas, while summer climate is essentially controlled by solar influences. In Winter and Spring well-defined storms cross the continent, and paths followed by the majority in any one year determine differences in amount of precipitation and ground-water storage of various areas in the region. In Summer the more or less regular passage of cyclones is absent, and rainfall is controlled largely by solar influences producing in some years abundant summer rains (usually of the thunderstorm variety, local in extent) and in others a dearth of precipitation resulting in drought.

Precipitation in the Valley

Year in and year out, we are concerned principally with the adequacy of precipitation (including rain and snow) to support vegetation, to promote agriculture, and to supply the earth with water for the numerous uses to which it is put by man.

Annual Precipitation: On the large map and Table I is shown the distribution of average annual precipitation throughout the Mississippi Valley. The first point to be emphasized is that the amounts shown do not mean that every year these quantities of precipitation may be expected. In some years these amounts will be considerably exceeded and, in others, will be considerably less. Moreover, the relative distribution shown on the map will rarely occur in any one year. The map merely gives a picture of an annual average precipitation which may be expected in a long term of years. It does present an accurate delineation of relative wetness or dryness in various parts of the Mississippi Valley.

TABLE 1.—*Annual precipitation in the Mississippi Valley* [1]

Subbasin	Drainage area	Percent of entire basin	Average annual rainfall	Average annual snowfall	Total precipitation	Equivalent proportion of total	
						Inches	Percent
	Square miles		*Inches*	*Inches* [2]	*Inches*		
Missouri	528,850	42.3	18.91	3.90	22.81	9.62	30.9
Upper Mississippi	187,850	16.0	28.72	3.10	31.82	4.78	15.4
Ohio	203,900	16.5	42.10	2.60	44.70	7.29	23.4
Arkansas	186,000	14.9	28.00	1.30	29.30	4.36	14.0
Red	90,000	7.2	39.40	.60	40.00	2.88	9.3
Lower Mississippi	54,300	4.3	49.37	.50	49.87	2.17	7.0
Total	1,250,900	100.0				31.10	100.0
Average			28.31 91%	2.79 9%	31.10 100%		

[1] From "Rainfall Characteristics of the Mississippi Drainage Basin." By H. C. Frankenfield, Trans. Am. Soc. C. E. vol. 93, 1929.

[2] Rainfall equivalent, actual depth of snowfall shown on fig. 4.

A glance at the facing map and Table 1 will show the following primary facts relating to distribution of annual precipitation.

1. The lines of equal annual precipitation (isohyetal lines) tend to run in a general north-and-south direction. This tendency is most pronounced west of the Mississippi. East of the river the isohyets tend to run northeast—southwest.
2. The annual rainfall is smallest on the west of the Mississippi Valley and increases gradually to a maximum to the east.
3. The only part of the Mississippi Valley having an average annual rainfall less than 10 inches is a small area centering in Big Horn County on the headwaters of the Big Horn

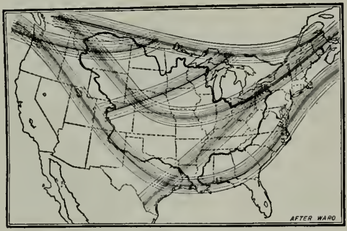

FIG. 3A-GENERALIZED WINTER STORM PATHS

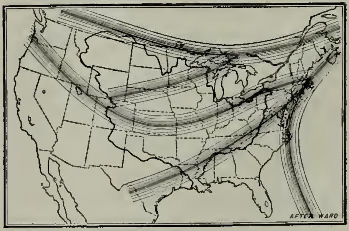

FIG. 3B-GENERALIZED SPRING AND AUTUMN STORM PATHS

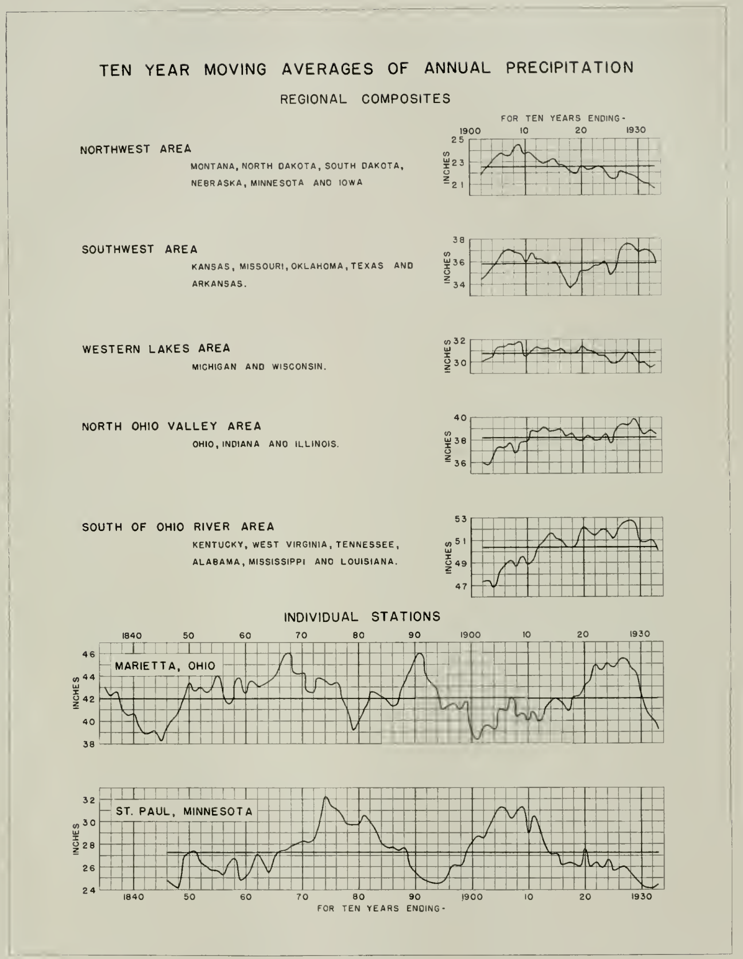
TEN YEAR MOVING AVERAGES OF ANNUAL PRECIPITATION
REGIONAL COMPOSITES
FOR TEN YEARS ENDING -
1900
10
20
1930
NORTHWEST AREA
MONTANA, NORTH DAKOTA, SOUTH DAKOTA, NEBRASKA, MINNESOTA AND IOWA
INCHES
25
23
21
SOUTHWEST AREA
KANSAS, MISSOURI, OKLAHOMA, TEXAS AND ARKANSAS.
38
36
34
WESTERN LAKES AREA
MICHIGAN AND WISCONSIN.
32
30
NORTH OHIO VALLEY AREA
OHIO, INDIANA AND ILLINOIS.
40
38
36
SOUTH OF OHIO RIVER AREA
KENTUCKY, WEST VIRGINIA, TENNESSEE, ALABAMA, MISSISSIPPI AND LOUISIANA.
53
51
49
47
INDIVIDUAL STATIONS
1840
50
60
70
80
90
1900
10
20
1930
MARIETTA, OHIO
46
44
42
40
38
ST. PAUL, MINNESOTA
32
30
28
26
24
FOR TEN YEARS ENDING -

FIGURE 5.

River in the central-western portion of Wyoming. This region is in a deep valley (elevation 3,800 to 4,800 feet) surrounded by mountain ranges of 7,000 feet. The average annual rainfall is about six inches. The minimum annual rainfall of record (1.20 inches) occurred at Hyattville in 1900. At this station there are generally not more than 28 days per year when precipitation occurs, and for the area as a whole not more than 40 days per year having precipitation.

4. The Great Plains region has for the greater part an average annual precipitation between 10 inches and 20 inches. The northwestern portion has between 10 inches and 15 inches.

5. There is a relatively uniform band representing average annual precipitation between 20 and 30 inches extending nearly north and south. If this amount of rainfall could be depended upon each year, crop production would be secure. Unfortunately there are large departures, often amounting to 50 percent or more, in the rainfall for any one year.

6. Throughout the central lowland region, the precipitation varies from 30 to 40 inches.

7. As the Appalachian Plateau is reached we find over the Ohio and Tennessee Basins average annual precipitation from 40 to 60 inches increasing to the east. This is the best-watered portion of the Mississippi Valley, affected by moisture-laden winds from both the Gulf of Mexico and the Atlantic Ocean. The rainfall is not only larger on a total annual basis, but is more equally distributed throughout the year than in regions to the west. This is shown by Figure 7.

8. Table 1 shows the distribution of annual precipitation over the principal sub-basins of the Mississippi. It will be noted from the last two columns that the relative water-producing abilities of the different portions of the Valley differ materially. Thus the Ohio Basin with less than 40 percent of the area of the Missouri produces 82 percent as much precipitation on an areal basis. Evidence of this is seen on the flow map as the Frontispiece of this report.

9. The maximum average annual precipitation (about 82 inches) occurs at Highlands, N.C., in the Blue Ridge Mountains. It is due almost entirely to local topographic features whereby heavy rainfall occurs from tropical hurricanes and from local thunderstorms in summer. The maximum annual rainfall of record was 111.20 inches in 1915.

Variation in Annual Precipitation: The long period annual precipitation may be widely departed from in individual years, or even for a term of successive wet or dry years. Regions vary in the extent to which the annual precipitation will approach the average. Figure 5[3] shows the 10-year moving averages for various regions in the Mississippi Valley. This figure indicates a pronounced decrease in annual precipitation in recent years in the northwestern and western lake regions and a tendency toward decrease in most other regions. Although much of the Valley is now in a period of low rainfall, every unbiased study thus far made by the Weather Bureau and other qualified agencies indicates that such low periods in rainfall will be succeeded by periods of high rainfall and there is every reason to believe that within the next few years rainfall in this territory will tend to increase.

Substantiation of this forecast is to be found from long term records of precipitation such as those shown at the bottom of Figure 5, presenting data for 98 years and 88 years at Marietta, Ohio, and St. Paul, Minnesota, respectively. It will be noted that periods of low precipitation even greater than that now being experienced have occurred, always to be succeeded by periods of high precipitation.

Of importance in activities dependent upon precipitation is the degree to which we may expect the annual precipitation in individual years to approach the long-term average. The annual precipitation in the Western portion of the Mississippi Valley is not only smallest in absolute amount, but is subject to the most frequent and largest variations from the average. When the average annual rainfall is low, say 15 inches as in Montana, a variation of four inches, nearly 25 percent from the average, is much more serious than in the wetter regions, say in Tennessee with about 50 inches average when a four-inch variation represents less than 10 percent.

Seasonal Distribution: On Figure 6 is shown the distribution of rainfall by months for areas within the Mississippi Basin where similar rainfall types prevail. It will be seen that nearly everywhere west of the Mississippi maximum precipitation generally occurs during May or June. This is, of course, ideal for agricultural purposes. East of the Mississippi the distribution of precipitation throughout the year is more uniform, often with two or more peaks, and with the minimum occurring in October or November. The average amounts of precipitation in the different regions during the several months are also shown on Figure 6.

Snow: The amount and distribution of snowfall as distinct from rainfall is important in many considerations of water use and control. Dashed lines on Figure 4 show the average annual depth of snowfall in the Mississippi Valley and details for the principal sub-basins are presented in Table 1. From the

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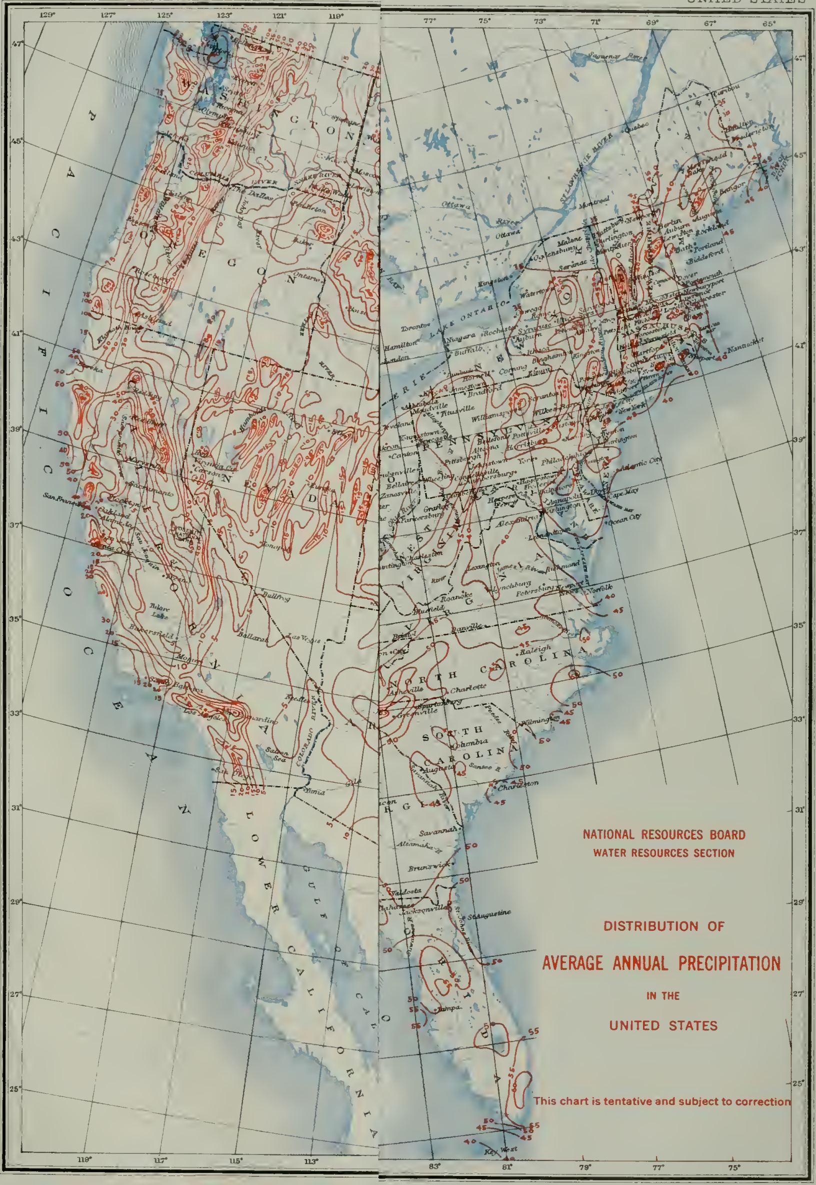
[3] Prepared from data by J. B. Kincer, U.S. Weather Bureau.

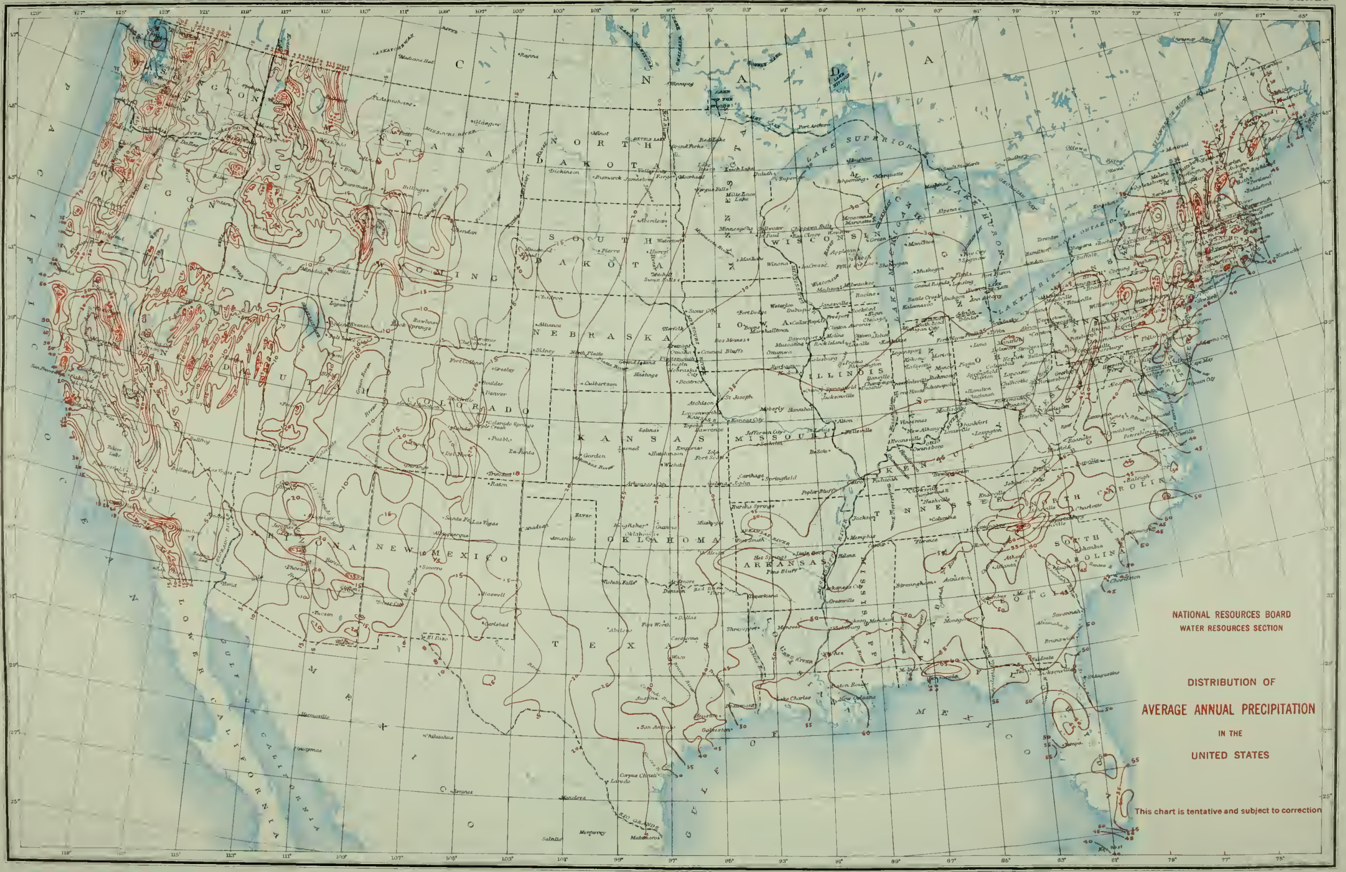


NATIONAL RESOURCES BOARD
WATER RESOURCES SECTION

DISTRIBUTION OF
AVERAGE ANNUAL PRECIPITATION
IN THE
UNITED STATES

This chart is tentative and subject to correction

Lines show average annual precipitation in inches



NATIONAL RESOURCES BOARD
WATER RESOURCES SECTION

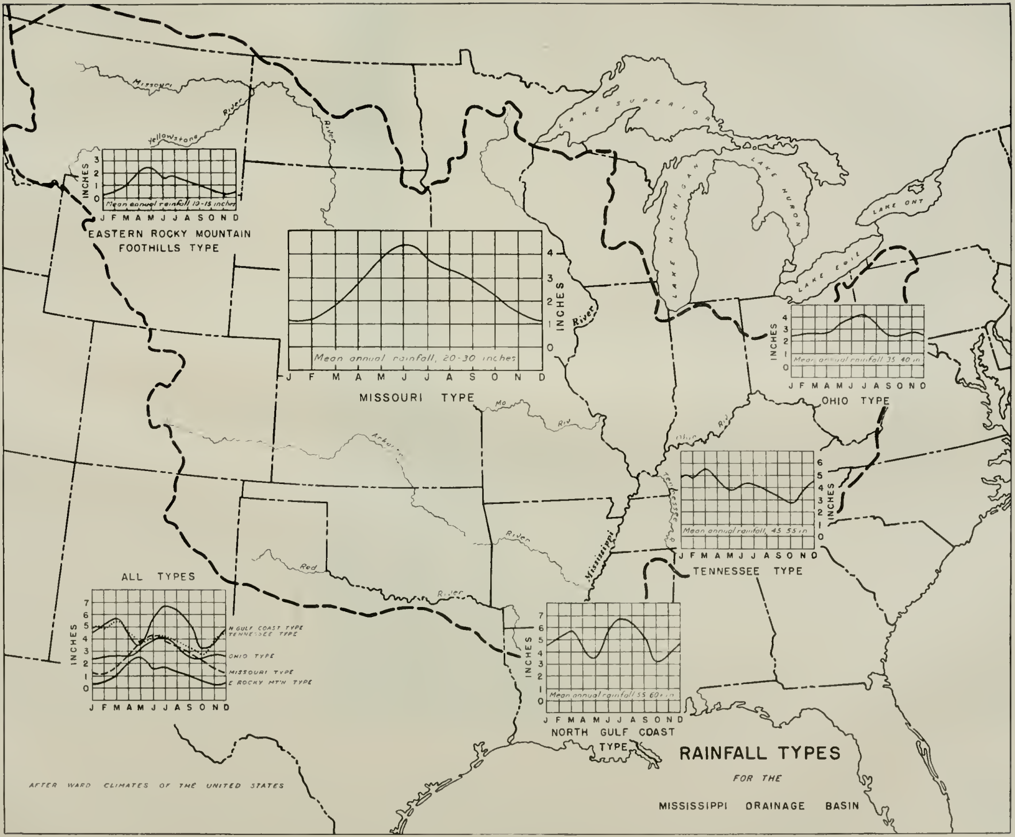
DISTRIBUTION OF
AVERAGE ANNUAL PRECIPITATION
IN THE
UNITED STATES

This chart is tentative and subject to correction

Lines show average annual precipitation in inches

Scale 1:11,875,000

100 0 100 200 300 400 500 600 Miles

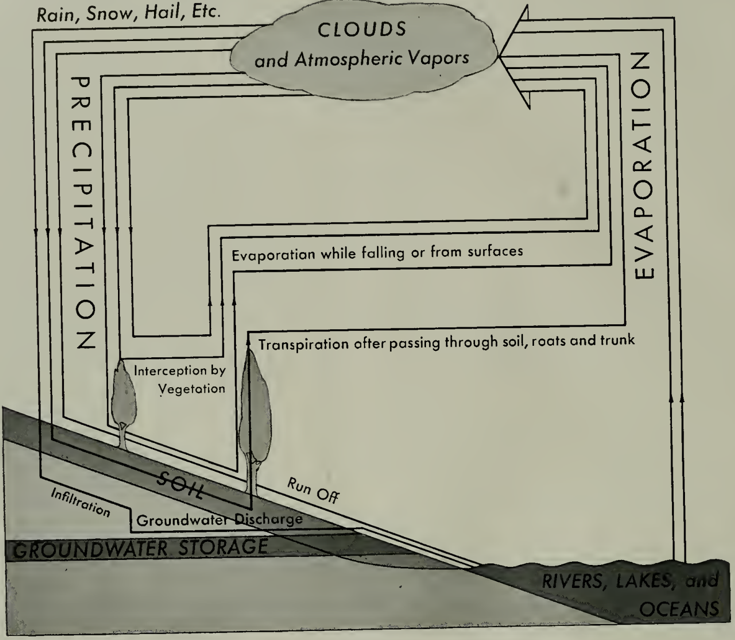


AFTER WARD CLIMATES OF THE UNITED STATES

FIGURE 6.

Precipitation and Run-off in the Mississippi Valley

Precipitation and the Hydrologic Cycle


Rain, Snow, Hail, Etc.
CLOUDS
and Atmospheric Vapors
PRECIPITATION
EVAPORATION
Evaporation while falling or from surfaces
Transpiration after passing through soil, roots and trunk
Interception by Vegetation
SOIL
Run Off
Infiltration
Groundwater Discharge
GROUNDWATER STORAGE
RIVERS, LAKES, and OCEANS

PICTORIAL STATISTICS, INC.

FIGURE 7.

"A drop of water, evaporated from the ocean, rains five times".—Anonymous.

standpoint of rain equivalence it is usually assumed that 10 inches of snow is equal to 1 inch of rain. Actually this is an average figure which may be widely departed from, depending upon the character of the snow, its degree of compactness, etc.

Run-off From The Basin

"All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come thither they return again."—Ecclesiastes 1:7.

The Hydrologic Cycle: To appreciate adequately the extremely complex and diverse phenomena attending the run-off from various portions of the Mississippi Valley, some brief consideration should be given to the disposition of the precipitation which falls on the region. On Figure 7 there is presented a generalized picture of the never-ending cycle described in the ancient biblical allusion quoted above. From this figure it will be seen that, of the precipitation condensed from water vapor in the air, most of it (perhaps 80 percent on the average) falls on the earth's surface. The remainder is intercepted by vegetation from which it is evaporated to the air, or is directly evaporated while falling by encountering dry and warmer air layers.

Of the precipitation which reaches the surface, some immediately runs off over the surface and is carried away by streams and rivers; some is evaporated from the ground or water surfaces, and some infiltrates into the ground. The relative quantity of effective total precipitation disposed of in each of these ways will vary greatly throughout the Mississippi Valley due to differences in temperature, agricultural practices, soils, seasons, and vegetative cover.

Subject to the wide regional and local variations, we may say that on the average, considering the Mississippi Valley as a whole, only between 10 percent and 40 percent of the total effective precipitation is reflected in surface run-off; from 10 percent to 25 percent is evaporated from ground, water, or tree surfaces; and from 35 percent to 80 percent infiltrated into the ground. Of the latter, a considerable portion is taken up by vegetation and used to produce vegetable matter or is transpired into the atmosphere from the leaves. Of the total effective precipitation, from 15 percent to 30 percent is disposed of in this way, leaving from 20 percent to 50 percent to be disposed of as ground-water flow, a considerable proportion of which ultimately reaches the streams and rivers through discharge by springs, and seepage.

Ultimately all precipitation is evaporated back to the air, completing the hydrologic cycle shown by Figure 7.

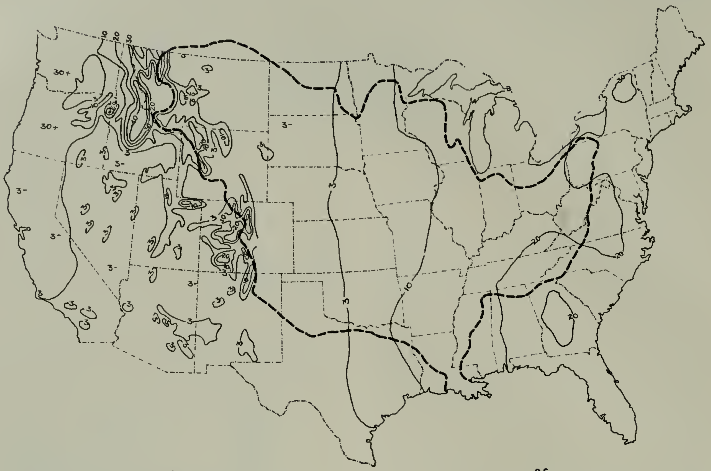
It is apparent that residual rainfall appearing as run-off in streams is less than half the precipitation. The various water losses are, therefore, of great importance and one might assume that to reduce these losses by artificial methods would be beneficial. This has been particularly advocated with reference to the largest of these losses—transpiration by vegetation. Certainly if we entirely denuded a relatively small region, the total run-off would be increased. But we must consider the matter from a broad regional basis. In the case of the Mississippi Valley the subject has been well presented by Zon, who says:

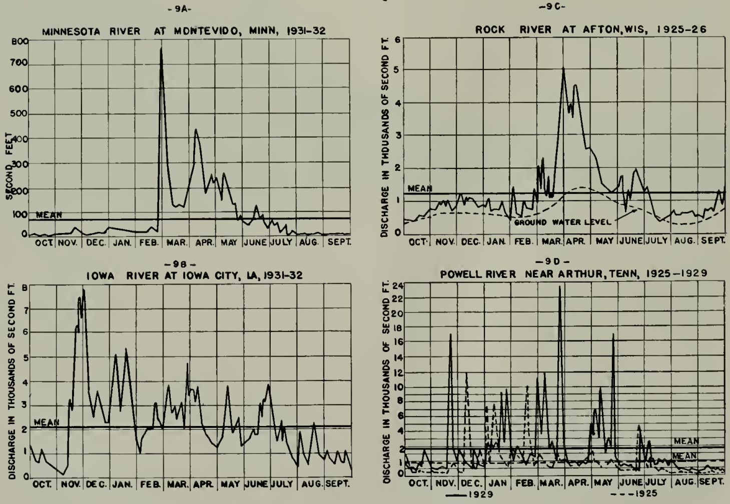
> As soon as the moisture-laden winds from the Gulf reach the land and encounter irregularities they are cooled and begin to lose part of their moisture in the form of precipitation. As long as the air currents remain saturated with moisture the slightest cooling or irregularity of the land that causes them to rise will result in precipitation. But as they move inland and become drier the remaining moisture is given off with difficulty and precipitation decreases. The sooner the humid air currents over land are drained of their moisture, the shorter, of course is the distance from the ocean over which abundant precipitation falls. If precipitation over land depended solely on the amount of water brought by the prevailing winds directly from the ocean, rainfall would, of course, be confined only to a narrow belt close to the sea. Not all the water that is precipitated, however, is lost from the air current. A large part of it is again evaporated from the land into the atmosphere. The moisture-laden air currents, therefore, soon lose the moisture which they obtain directly from the ocean, but in moving farther into the interior absorb the evaporation from the land. Hence, the farther from the ocean the greater is the proportion which evaporation from the land forms of the air moisture. In fact, at certain distances inland practically all the moisture of the air, or at least as great a part as that formed originally by the water evaporated direct from the ocean, must consist of that obtained by evaporation from the land.

Annual Run-off: Since run-off is the residual from precipitation after the demands of evaporation and transpiration have been met, it is subject first of all to the various factors affecting the amount and distribution of precipitation. In addition it is affected by character of soil, topography, ground, and surface storage. The annual run-off in streams and rivers represented as equivalent inches depth on the

Precipitation and Run-off in the Mississippi Valley

MAP OF UNITED STATES, SHOWING ANNUAL RUN-OFF IN DEPTH IN INCHES





HYDROGRAPHS OF TYPICAL RIVERS IN MISSISSIPPI RIVER BASIN
FIGURE 9.

drainage area is roughly shown by the lines on Figure 8. Such a map cannot show the numerous large variations in annual run-off which occur locally and which are due to the various influences just described.[1]

For the Great Plains region, having rainfall from 10 to 15 inches, the average run-off is only about three inches or from one-third to one-fifth of the rainfall. In many parts of this region the run-off is materially less than three inches, often becoming less than one inch.

Passing east with increasing rainfall, there is naturally an increase in run-off. This averages from 10 to 20 inches and increases to a maximum of 40 inches in the small area in the Blue Ridge Mountains in Western North Carolina where there is the highest rainfall. Run-off east of the Mississippi will average generally 35 percent to 45 percent of the rainfall.

Seasonal Run-off: The total run-off during the year is of little importance to most human activities as compared with the manner in which it is distributed throughout the year. On some small drainage areas in arid regions nearly the entire annual run-off occurs as the result of a few heavy rainfalls, the streams becoming nearly or quite dry for much of the year. Over considerable portions of the Great Plains, as indicated by the precipitation diagrams on Figure 6, over 50 percent of the precipitation occurs during the four months April to July. This is reflected by a smiliar pronounced seasonal distribution of run-off.

The seasonal distribution of run-off in other regions of the Mississippi Valley follows more or less the distribution of rainfall. However, there is no simple relationship between either the seasonal distribution or amount of rainfall and the resulting run-off. A comprehensive study of such relationships as can be shown to exist, and the idiosyncrasies of different parts of the Mississippi Basin in this respect, is being made in collaboration with the U.S.G.S.

On Figure 9 are shown the hydrographs (graphs of daily flow) of a few typical streams in the Mississippi Valley. The distinctly seasonal character of the run-off from many streams west of the Mississippi River and in the Great Plains region is well illustrated by Figure 9a. The need for storage to equalize the flow is apparent. Figure 9b indicates a different distribution of flow in a region not very distant from that indicated on Figure 9a. In Figure 9c is shown a marked seasonal distribution of flow from a highly glaciated area where, for most of the year, it is due to discharge from ground water storage, the variations in height of the ground water table being shown by the dashed line. Figure 9d shows a typical Tennessee Valley stream in a dry and in a wet year. The flashy character of the discharge is evident, showing need in this region for regulation by storage for a somewhat different reason than on streams illustrated by Figure 9a.

Floods in the Mississippi Valley

Floods are a normal event in most rivers and occur each year at about the same time. The annual Spring flood is looked to by agricultural interests and those concerned with water supply water power, and irrigation developments as a source of needed water to be stored by the ground or in surface reservoirs for beneficial use. Over the greater part of the Mississippi Valley the normal Spring rise of the rivers takes place in March or April.

Great Floods: When the rainfall has been of long duration, of much greater quantity than normal, of wide distribution; and when it falls on ground already filled with water, or frozen, the stage is set for a great and probably destructive flood. In general, the larger the drainage area, the less the flood discharge per unit of the total area. That is, the discharge at New Orleans for instance, even in the greatest flood is less in terms of cubic feet per second per square mile of tributary drainage area than in many floods occurring fairly frequently on tributaries, such as the Illinois River. However, the causes producing great floods on a large area are likely to be present in conjunction less frequently than on small areas. In consequence of the enormous volume of water to be disposed of in a great flood on a large stream and the relative infrequency of occurrence, adequate protection against such floods is likely to be absent, so that when they do occur the damage is often very great over unexpectedly large areas.

Droughts in the Valley

Great floods are often, perhaps usually, relatively local phenomena. Great droughts always have a large regional aspect, being affected by major (though temporary) changes in the atmospheric circulation over wide areas of land and sea. Floods occur, produce damage, and are quickly gone. They may always be controlled by men if there is sufficient justification for the expenditure involved. Droughts come on insidiously, last a long time, and may affect agriculture and other human activities for years after normal rainfall returns.

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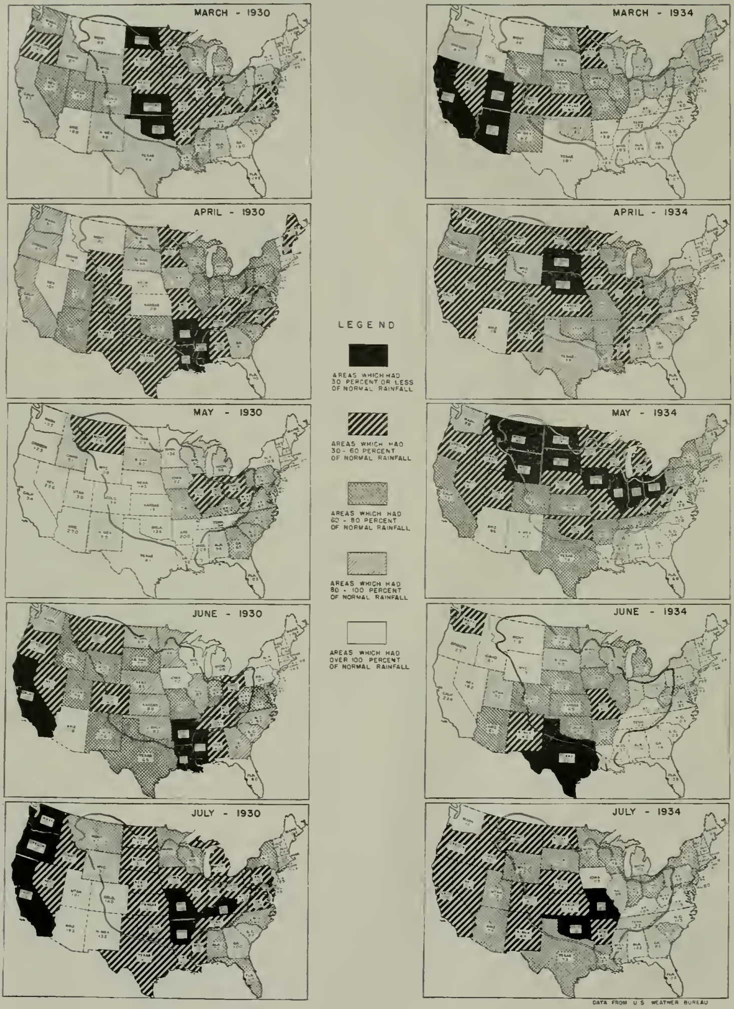
[1] Issued in 1908 by the U.S.G.S., this map will be superseded by one prepared by the Water Resources Section of the National Resources Board and will appear in the Board's report.

DEVELOPMENT AND INTENSITY OF 1930 AND 1934 DROUGHTS


MARCH - 1930
MARCH - 1934
APRIL - 1930
APRIL - 1934
MAY - 1930
MAY - 1934
JUNE - 1930
JUNE - 1934
JULY - 1930
JULY - 1934
LEGEND
AREAS WHICH HAD 30 PERCENT OR LESS OF NORMAL RAINFALL
AREAS WHICH HAD 30 - 60 PERCENT OF NORMAL RAINFALL
AREAS WHICH HAD 60 - 80 PERCENT OF NORMAL RAINFALL
AREAS WHICH HAD 80 - 100 PERCENT OF NORMAL RAINFALL
AREAS WHICH HAD OVER 100 PERCENT OF NORMAL RAINFALL

DATA FROM U S WEATHER BUREAU

FIGURE 10.

Man has thus far been unable to control climate over a sufficiently large area adequately to mitigate the effects of severe droughts.

The Mississippi Valley, being a great interior basin, is particularly susceptible to the causes that produce great drought. The western portion of the Valley, shut off by mountain ranges from moisture-bearing winds from the Pacific, devoted in large part to important agricultural pursuits for which the normal rainfall is barely adequate, constitutes a national problem in the management of water resources which is dramatically presented to the public attention by the effects of the severe drought recently in progress.

Droughts are caused by prolonged deficiencies in normal rainfall, often extending over several years, so that the cumulative effect of lowered ground water levels is superimposed upon seasonal rainfall inadequacy. The long-period rainfall records at St. Paul, Minn., and at Marietta, Ohio, shown on Figure 5 clearly indicate severe drought conditions recurring at intervals of from 30 to 40 years, and also that generally droughts in Minnesota are not synchronized with droughts in Ohio.

As time goes on larger areas have been brought under cultivation, and the effects of droughts become more wide-spread. Thus the 1930 drought was generally regarded as of nearly unequaled severity, and not likely to be again experienced for many years. Now, less than four years after this occurred, much of the same territory is experiencing a still more severe lack of water. Actually the deficiencies in ground water have never been replenished since 1930, and rainfall deficiencies recurring, the present drought is the result of cumulative conditions which have been going on for some years.

The differences between the 1930 and 1934 droughts are strikingly shown by Figures 10a and 10b. The 1934 drought began under the influence of unusually low Winter and Spring precipitation in many of the states west of the Mississippi and extending east over the central lowland region. Reference has already been made to the seasonal character of the precipitation in these parts of the Mississippi in the discussion of Figure 8. The greatest deficiency in precipitation came during those months when it is normally highest and most needed for ground water replenishment and crop production. In 1934 there was experienced at many points the least precipitation and the lowest river stages ever recorded.

GROUND WATER AND THE WATER TABLE

GROUND WATER AND WATER TABLE

Importance

Subsurface water plays an essential role in the water supply of the Mississippi River Basin. Agricultural activities, rural development, and especially in times of drought the flow of surface streams are dependent on subsurface water. Outside of the larger cities, probably 95 percent of the people of the Mississippi River basin depend on subsurface water for domestic and stock watering purposes. Subsurface water supplies soil moisture to crops, several inches of water annually being required for plant growth. The depth and amount of subsurface water available in this region is of the utmost importance to its inhabitants.

There are great variations in the position of the ground water level [1] beneath the surface of the earth. Cycles or irregular periods in amount of rainfall, periods of excessive rainfall, and periods of drought cause the larger fluctuations. These are not, however, permanently progressive. A progressive decrease in ground water level has been taking place in parts of the Mississippi River Basin, particularly in the Middlewest and the near Northwest. This has manifested itself in the disappearance of surface waters and in the need for deeper wells. On the other hand, in the more humid portions of the Basin there is at hand no conclusive evidence of a permanent measurable decrease in the ground water supply. A study now in progress may give more conclusive evidence on this point.

Changes in the Humid Regions

Stream flow is maintained during drought periods by ground-water discharge. The amount of ground-water discharge decreases if the ground-water level increases in depth. If severe droughts of equal intensity have occurred many years apart and at the same season of the year, the minimum ground-water flow would be less and the rate of decline of the stream flow greater in successively later droughts, if there had been a considerable lowering of the water table during the intervening periods.

A comparison was made of the precipitation and the stream flow on certain drainage areas of the Mississippi Valley during drought periods which throws some light on changes that may have occurred in the water table level and ground-water conditions during the period of time covered by such records.[2] Only those rivers were used for this comparison which are free from material diversion and regulation.

Such data are available for the following rivers

Iowa	Skunk River, Des Moines River.
Wisconsin	Black River, Rock River.
Indiana	East Fork of White River.
West Virginia	Kanawha River.
Kentucky	Kentucky River.
Ohio	Miami River.
Tennessee	Holston River.

Comparing the severe drought of 1930–31 with earlier droughts, the Skunk River and Des Moines River show a relative decrease in run-off in the 1930–31 drought. The Black River and Rock River show practically no change. The rivers east of the Mississippi River show no relative decrease in run-off in the 1930–31 drought, but actually show a lower deficiency in run-off in the 1930–31 drought than in the earlier droughts. With the exception of the Iowa rivers, therefore, the stream run-offs in drought periods in the more humid portions of the Mississippi River Basin give no evidence of lowering of the water level or of a decrease in ground water supply. The Iowa rivers are dependent on the portion of the Basin for which there is evidence of lowering of the water table. In the other cases if any lowering has taken place in the valleys, it is to be measured in inches. On the higher slopes, locally, there may have been greater lowering.

A more direct method of determining changes in ground water level is by a comparison of water level in wells over a long period of time. But no systematic study of water level in wells in the more humid portions of the Basin has been made. Conclusions based on generalized impressions seem to indicate that there has been some lowering, but the amount of change, if any, is unknown. False impressions of depletion may be gained by the necessity of deepening wells in periods of drought, by increased needs for water requiring additional and deeper wells, and by leakage from casings and clogging of intakes of old wells.

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[1] DEFINITIONS.—*Zone of Saturation:* The permeable rocks below a certain level are generally saturated with water. These saturated rocks constitute the "zone of saturation."

Ground Water: The subsurface water in the zone of saturation is called "ground water." It supplies springs and wells.

Ground Water Table: The upper surface of the zone of saturation in permeable rock or soil is called the "ground water table." When the upper surface is formed by impermeable rock, the water table is absent.

Ground Water Level: Ground water level is a less technical synonym for ground water table.

[2] Detailed reports such as Report PW 14985 covering investigations of ground water and water table levels in the Mississippi River Valley are in the files of the Mississippi Valley Committee.

Changes in the Arid and Semiarid Regions

In the more arid portions of the Mississippi Basin reliable evidence of changes in water level and depletion of ground water cannot be obtained from records of stream flow in periods of drought, because these rivers are subject to too much diversion and regulation. Records of changes in level of water in wells must be depended upon for tangible and measurable evidence of changes in the ground water level. Such evidence was compiled for the Red River and Middle Missouri River Basin, embracing North Dakota, eastern South Dakota, Nebraska, Kansas, and western Minnesota, western Iowa, and western Missouri.

The most accurate method of obtaining knowledge of the fluctuations of ground water level is through observations on test wells over a long period of years. Because this method was not feasible for the present report, detailed questionnaires were sent out to 4,683 well drillers for basic information regarding changes in ground water levels since the settlement of the region. Their replies furnished definite evidence of lowered ground water level and of the amount of lowering.[3]

Usable replies were received from 1,482 drillers, or 31.6 percent. The questionnaires included "well driller's report" and "well record" sheets. The well driller's report sheets comprised 15 major questions: the length of experience of the driller; details as to (*a*) shallow water wells, (*b*) second horizon water wells, (*c*) third horizon water wells, and (*d*) deeper horizon waters; general changes in ground-water conditions (*a*) based on drillers' experience and (*b*) based on tradition since earliest settlement; and changes in flow of springs, ponds, and streams. The well record sheets comprised 18 questions; the location of individual wells; their position; character of aquifer; water level and changes in level; and yield and changes in yield. The replies were tabulated by counties on "county data sheets."

From the data it is evident that the northern (North and South Dakota and Minnesota) and North Central (Nebraska and Iowa) states show changes in ground-water level of more than 10 feet and that the South Central group (Kansas and Missouri) show a predominance of changes of less than 10 feet. The Tri-State Zinc Mining District in southwestern Missouri and southeastern Kansas shows greater change due to excessive drainage through mining operations. The data tend to show greater changes in level in the west than in the east.

Considered as significant in the data compiled is the mean change in head by counties. The county range by states of the mean decrease in head and the range in time over which they took place are:

State	Range of county averages	
	Years	Lowering of head in feet
North Dakota	10–25	6–34
South Dakota	2–35	0–70
Minnesota	12–43	5–24
Nebraska	16–36	4–26
Iowa	7–39	0–21
Kansas	10–44	2–13
Missouri	11–30	0–26

Ground Water Summaries

North Dakota: The amount of change in ground water from east to west is marked. Large areas in the western part of the state have a decrease of more than 20 feet.

Minnesota: Shows a change of from 10 to 20 feet. Only two large areas show changes of less than 10 feet—the morainal lake district in Stern, Todd, and Wadina counties; and the area of Dakota sandstone outcrop in Nobles, Murray, Lyon, Lincoln, and Lac qui Parle counties. The 15-foot contour of depression follows the boundary between the morainal lake region in which the depression is between 10 feet and 15 feet, and the Red River Valley in which the depression is 15 feet to 20 feet. An area of more than 20 feet depression lies along the divide between the Red River basin and the Minnesota River basin.

South Dakota: The changes in level are very irregular and range from less than 10 feet to more than 35 feet.

Nebraska: The changes are variable and range from less than 10 feet to more than 20 feet, but there are none of more than 30 feet.

Iowa: Shows a fairly uniform drop throughout the state. The area of less than 10 feet drop is about the same as the area of more than 10 feet drop. Along the divide bethe Mississippi and Missouri rivers is a drop of from more than 20 feet to a maximum of more than 30 feet.

Missouri and Kansas: Generally show changes of less than 10 feet. Small areas showing more than 10 feet are due to exceptional local causes.

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[3] See footnote [2].

Surface Water Summaries

North Dakota: Springs are generally weakened and in most counties dry. Ponds are completely dry. Lakes show a lowering of 2 to 11 feet and are mostly nearly dry. Streams are mostly dry. Rivers are dry or very low. Even some of the larger rivers have flow only in spring.

South Dakota: Springs are weakened or completely dry. Ponds are dry. Lakes show average lowering of more than 9 feet. Streams are nearly all dry. Rivers show average lowering of 6 feet and some are dry.

Minnesota: Only the strongest springs are flowing. Ponds are dry except in lake district. Lakes show average lowering of 7 feet. Most streams are dry. Rivers have decreased more than 6 feet in level.

Nebraska: Decided reduction in flow of springs and some dry. Ponds mostly dry. Lakes lowered 7 feet and some dry. Streams nearly all dry. Rivers' average lowered 5 feet.

Iowa: Springs weakened and many dry Nearly all ponds dry. Lakes average 6 feet lower than normal. Streams are 5 feet lower or dry and rivers 6 feet lower.

Kansas: Springs weakened considerably and some have only seasonal flow. Ponds are mostly dry. Lakes are nearly all dry. Streams have little or no seasonal flow. Rivers lowest in history, averaging 5 feet drop.

Missouri: Some springs show no change, but generally are weaker and some dry. Ponds mostly dry but mainly due to drainage. Lakes are generally lower. Streams are nearly dry. Rivers lowest in history, averaging 5 feet drop.

Artesian Summary

Artesian water conditions are such that flowing wells occur only in a limited number of the counties, chiefly in South Dakota and North Dakota. A summary follows.

North Dakota: The Dakota artesian basin shared with South Dakota and in part with Minnesota and Nebraska is one of the most important in the world. Due to careless drilling and finishing of wells, to unlimited waste of water, and to failure to control old wells, wild wells, and leakes, the pressure and supply of this basin has been rapidly depleted. Wells have ceased to flow over large areas. Unless this waste is checked, most of the area will cease to yield flowing water. The danger was recognized by the North Dakota legislature in 1921 in the passage of an artesian water conservation law. Its enforcement has already greatly reduced waste, checked decline in pressure, and kept wells flowing that otherwise would have since failed. This is the only state in which serious attempt has been made in artesian water conservation. The decrease in head in North Dakota during the past 18 years has been 18 feet, or one foot per year.

South Dakota: South Dakota presents the largest decrease in head of artesian waters. In 20 years the decrease has been at least 40 feet.

Minnesota: Most of the flowing wells are in glacial sands and gravels. Their head has decreased 4 feet in 20 years. Artesian wells in the Dakota basin are few in number. Their loss in head is much greater, but reports in feet are insufficient for a useful estimate.

Nebraska: Few counties in Nebraska report flowing wells. Most of them are in the Dakota basin in the northeastern portion of the state. A general decrease is shown in 24 years but not as marked as in South Dakota.

Iowa: A few flowing wells are reported in western Iowa. They are shallow and draw their supply from glacial drift or the Dakota sandstone immediately under it. They are in narrow deep valleys and show little change in 22 years.

Kansas: Considerable decrease in head is reported in shallow wells and little decrease in deeper wells.

Missouri: Very few artesian flows are reported. In a few localities they show decrease in head, others show no change.

Conclusions to be drawn from available data indicate that:

1. There has been a universal lowering of ground-water levels throughout the entire area during the entire period of settlement, varying on the average in different states from 8 to 17 feet.

2. The decrease was small early in the period, was greater during the twenty years' experience of the present well drillers, still greater in the past ten years, and greatest in the past five years.

3. The greatest decrease in ground-water levels occurred in the northern and western states, and the least in the southern and eastern.

4. The evidence of decreased ground-water level in wells is corroborated by the decrease in flow and drying up of streams and springs

and by the lowering of levels and drying up of lakes and ponds.

Causes and Prevention of Change

The supply of ground water depends on amount of rainfall, the percentage of rainfall that enters the zone of saturation, and the amount that is withdrawn from the zone. Under a balanced set of conditions withdrawal equals intake and a stable water level is established. That level will be lowered if there be a permanent decrease in rainfall, if there be a change in surface conditions that results in a smaller percentage of the rainfall percolating into the soil and penetrating to the level of ground water, or if there be withdrawals in excess of the inflow.

With the spread of population across the Mississippi Valley Basin there has been an increasing demand upon the ground-water supply. Without realization that this water supply is not unlimited, it was used freely and wastefully, and progressive exhaustion set in. Recognition of this on the part of North Dakota has led to a decrease in the rate of exhaustion. Similar action throughout the region should yield equally beneficial results in retarding the lowering of the water level.

The settlement of the Mississippi Valley Basin has changed the character of the terrane. Original vegetation has been replaced over large areas by planted crops. Vegetation covering in places has been increased, in other places decreased. Cultivation has changed the physical character of the soil, increasing infiltration in places, decreasing it in other places. Changes in drainage have changed the percentage of rainfall that goes as run-off and consequently changed the percentage that find its way into the zone of saturation. Some of these factors have increased and some have decreased the amount of water that goes into the zone of saturation. There is considerable difference of opinion not only with respect to the quantitative effect of these factors but even as to the direction of their effect, that is, whether they have increased or decreased the increments to the ground-water supply. Equally divergent are the opinions concerning the net result of all the changes in the region brought about by its settlement.

The water table will be lowered if infiltration has been decreased or if transpiration and evaporation have been increased through change in type or amount of vegetative cover. Increasing vegetative growth where the soil surface is pervious increases the demand on soil moisture and decreases thereby the water available for recharge. On the other hand, where the soil is impervious, increasing vegetation will decrease surface run-off and may increase ground water. Whether cultivation increases or decreases infiltration is a moot question. It works one way under one set of conditions and the opposite under another set.

In the border zone between the arid and humid regions ground water conditions are apparently the most critical. In these areas the change from grass to crop appear to have reduced infiltration and increased transpiration to such an extent as to diminish the supply of water available to maintain the water table. It seems improbable that the deepseated supplies have been materially affected by man's occupancy of these areas because their source is precipitation at the outcrops of the aquifers which are in other areas.

We do not know definitely, and probably never will know, all the factors involved in the hydrologic cycle of rainfall run-off, infiltration, evaporation, and transpiration, nor the effect of man's activities on these relations. Conclusions drawn and plans made on the basis of the meager information now available may later prove illogical and inappropriate.

In a continental area as vast as the Mississippi Valley Basin some precipitation doubtless comes from inland sources rather than the ocean. Increases in atmospheric moisture through evaporation and transpiration should increase precipitation. Steps to bring about such a condition would include the creation of innumerable flood water reservoirs, the cessation of drainage, and the maintenance of a vegetative growth that will transpire the maximum amount of soil moisture. Such measures might increase precipitation in the region, but there is still no assurance the precipitation will fall where most needed or that it would augment the ground water supply. If such measures were sound, it might be asked why there was no apparent increase in precipitation following the conversion of 20,000,000 acres of desert into intensively irrigated land in the West.

In conclusion it may be accepted with confidence that the information at hand is so strongly suggestive of recession of the ground water table and depletion of the sub-surface water resources in certain areas as fully to warrant an immediate and definitely comprehensive investigation to determine the critical facts for those portions of the basin where subsurface water resources are of paramount importance in the water economy of the region.

SOIL EROSION

The Situation

Soil is one of the most precious of the country's natural resources. Upon its protection and wise use depend not only the ability of the nation to provide food and other essential products for its people but also the economic stability of a large part of the population. The soil of this country has not been properly protected, nor has it been wisely used. In a vast area, in the aggregate, land is progressively being impaired for agricultural use by the wearing and cutting forces of water and wind.

The extent of damage by soil erosion, its disturbing effect on stream flow, and its far-reaching economic and social consequences create one of the most important and urgent problems now confronting the nation. The problem is urgent because erosive processes that are depleting soils are unceasing and relentless in operation and efforts to apply measures to check erosion have failed to reach more than a small part of the productive land that is in process of economic decline. Acceleration of injury of soils by erosion is far more rapid than gains by extension of control measures. Each year there is a large net loss, a steady undermining of the physical foundations of a permanent agriculture.

It is estimated that 75 percent of the tilled land of the country is being reduced in productive value by erosion. Estimates indicate that a large portion of the agricultural land in the Mississippi Basin has lost from three to six inches of the top soil, and that on no less than 25 percent of tilled lands in the Basin the top soil has actually been stripped to the subsoil. Gullying of land represents an advanced stage of surface erosion and often means the final and permanent ruin of land for cultivation. Already about five percent of land in the Mississippi Basin is estimated to have passed into this condition.

The causes of accelerated and dangerous soil erosion are to be found in the effort to cultivate steep slopes, in failure of farmers to use effective measures of tillage and, where necessary, of terracing, in injury by forest fires, and in abuse of land by overgrazing of livestock.

Research and practical experience have demonstrated that soil erosion, such as is caused by human activities, can be controlled to an extent that will make possible the occupancy and use of the land with a high degree of security and permanence. Effective measures of control are, however, now in actual application on less than one-sixth of the tilled land naturally subject to erosion in the Mississippi Basin. Unless vigorous public action to check soil erosion is initiated at once, on a scale commensurate with the real situation, it will be too late to save vast areas of our most productive land from permanent depletion.

Action of Water

Water is the chief agency causing erosion. Supplied by the fall of rain and by melting snow, it flows rapidly over slopes absorbing in solution a large amount of soluble materials and progressively moving surface particles of soil. Both inorganic and organic materials are swept into the streams. The coarser material is dropped near the point of its origin, and often, in case of torrential flows, spread over valuable land. The more finely divided particles are carried in suspension and either deposited along the banks of the streams or in the channels, or carried to sea.

The first effect of surface run-off of water is to impair the valuable topsoil. There is a leaching out of the plant nutrients, dissipation of the humus and other organic matter, disappearance of the beneficial bacteria and soil fauna, a break-down of the porous condition of the soil, a compacting of the surface that lessens absorption and infiltration of water, and finally a movement of the upper layers of the soil itself. Thus, as a result of human activities, water, a vitally essential substance in plant life, becomes an agency destroying the fertile portion of the soil that has required upwards of 1,000 years of natural processes to create.

Types of Soil Erosion

The first manifestation of erosion is a more or less uniform wearing down of the soil, technically called *sheet erosion*. Often it is not obvious except by changes in color of the soil or by the lowering of productivity. If preventive measures are not used, the surface flow of the water often breaks the surface and forms minute shallow furrows in which water tends to accumulate. This is called *rill erosion*, *fingering*, or *shoe-string erosion*. Such a condition is, however, only temporary. With exposure to many storms the tiny channels are deepened and widened and are transformed into gullies which increase in depth and width down the slope. *Gully erosion* may start, on readily erodible land, from almost any depression or break in the surface of the soil, as for example, a plow furrow running up and down the slope, a drainage ditch, a wagon track, a cattle trail, and in the forest a wood road, path or skidding trail. Such gullies are often fifteen to twenty feet deep.

In some soil formations there is a caving of the banks of gullies through the undermining influence of water, forming an amphitheater type of gully. The banks are vertical and the surface run-off from the adjacent land flows into the gully as veritable waterfalls, accentuating the scouring of the base of the banks and increasing the caving process. Sometimes these caving gullies reach a depth of two hundred feet and a width of eight hundred feet. In addition to the foregoing types of erosion there is so-called *stream erosion* where streams and rivers scour channels in the flood plain or cut the banks.

Conditions Affecting Water Erosion

Rainfall: The amount of water which falls on the soil is a major factor in erosion. More important is the character and seasonal distribution of rainfall. If the rainfall is well distributed through the year and is largely in the form of gentle rains, there is far less soil erosion then when the storms are violent and a large quantity of water falls on the ground in a short period. Rapid melting of snow is frequently the cause of excessive erosion.

Slope: On a given area of land steepness of slope governs velocity and the erosive power of a specified volume of water running over the surface or through gully channels. The erosive power and the transporting power of water vary in geometric proportion with its velocity. Steep slopes therefore erode more readily than gentle slopes. Erosion increases the gradient and hence the velocity of run-off, and causes an ever-accelerating rate of movement of soil.

Character and Condition of the Soil: Erosive forces act differently on soils of different structure and texture. Broadly speaking, the more porous the soil the less danger of erosion. The admixture of humus with the soil particles is effective in reducing the erodibility of soil. It increases and maintains the porosity of heavy soils and acts as a binder of soil particles of coarse texture. An important factor in erosion, also, is the condition of the soil from the standpoint of moisture content, exposure to freezing and thawing and to frost heaving, and character of tillage.

Vegetative Cover: A cover of forest is the most effective agency in controlling soil erosion. A matting of fallen leaves and other material carpets the soil. The roots of the trees and other plants extend into the soil in all directions seeking moisture and nutrient and form an intricate network that holds the soil in a cohesive mass. The forest canopy breaks the force of the falling rain which reaches the ground with only light impact. The stems of trees and smaller plants, and the leaves, dead branches, and other debris on the ground act as a mechanical check to the surface run-off, permitting gradual infiltration of water into the soil. The humus from the decomposing litter develops and maintains in the soil a high degree of porosity. Under such conditions soil erosion is at a minimum.

Natural associations of grass and other harbaceous plants in open prairies develop a firm sod with interlacing roots and serve to hold the soil in place. Here too the dense cover of plant stems presents a check to surface run-off, and the accumulating humus keeps the soil porous for water absorption and penetration. In the semi-arid regions vegetation is more sparse than on long-grass prairies and in forest regions. The tufts of plants, weeds, and dryland shrubs are frequently interspersed with bare soil. Under such conditions the soil is especially exposed to erosion when the rains fall. Abuse of western ranges by overgrazing has already greatly reduced the vegetative cover, compacted the soil, and caused accelerated erosion on a large scale.

Crop Cover: There is a great variation in the effect of different crops on the extent of erosion under given conditions of topography and character of soil. The rate of erosion is greatest with open-grown crops like corn, cotton, and tobacco, is much less under rotations of open- and close-grown crops, and least with sod-forming crops like alfalfa. This is well illustrated by experiments at the Missouri Agricultural Experiment Station during 1917 to 1923 on Shelby loam soil, with a slope of 3.7 percent. The rate of movement of soil was: from bare land, 34.8 tons per acre annually; land in continuous corn, 17.7 tons; continuous wheat, 6.6 tons; rotation of crops—corn, wheat and clover, 2.8 tons; and sod-grass, 0.29 tons.

The foregoing principles form the basis for skillful use of crops in control of erosion.

Wind Erosion

The action of the wind as an agency in erosion is most evident in arid regions where extensive areas of soil are bare or only sparsely covered with vegetation. Wind erosion is a very serious factor today in the dry and windswept portions of the Mississippi Valley. Vast areas of land formerly protected by a cover of grass and other types of vegetation have been tilled or heavily pastured. Wind erosion is always most severe during prolonged periods of drought, such as that characterizing portions of the central West during the past few years.

On extensive areas the soil became thoroughly dried out and the pulverized top soil rendered peculiarly susceptible to movement by the wind. The soil in many places drifted like snow, piling up against fences and other surface obstructions and filling roadside ditches. The finer particles were carried into the air, some of the material being deposited at various points in nearby sections and other portions blown hundreds of miles away.

The spectacular dust storm of May 11, 1934, followed very severe and drying winds in the West, carrying fine soil particles over the Atlantic States for distances of 1,500 miles and noticeable over an area of 1,000 miles in width, extending from North to South. For the most part the material transported by the wind was derived from the topsoil of fields and pastures now in use. In many sections that have been in cultivation for only 8 to 12 years, the rich topsoil has already been largely lost as a result of wind erosion.

Consequences of Erosion

It is impossible with our present knowledge to measure in full the consequences to the nation of erosion which is now taking place. In the following paragraphs there are indicated some of the features of loss.

Injury to Land: The progressive washing away of the top soil from the best farm lands of the country represents altogether the most serious aspect of erosion. The top soil, which on many acres averages only seven to eight inches in depth, may be worn away in from twenty-five to fifty years. This is a small period in the life of a nation. H. H. Bennett, Director of the U.S. Soil Erosion Service, estimates that already 125,000,000 acres of land now under cultivation have lost all or most of the productive surface soil by sheet erosion. The loss of plant nutrients by erosion also reaches staggering figures. The final destruction of land for agriculture is accomplished by the deep cutting of fields by gully erosion. This form of erosion has been a chief factor, according to Bennett, in the virtual ruin of about 35,000,000 acres of formerly tilled lands in the United States. Though the loss by gully erosion is very great, the injury to agriculture is far less than that caused by sheet erosion.

Increased Run-off: Land abuse results in lessening the factors which retard the run-off of water from slopes. Sheet erosion reduces the power of the soil for absorption and infiltration of water and thereby increases run-off. Where gullies are formed the surface water is carried off in channels which at their heads have a gradient steeper than the general land slope, and the gullies also drain the underground water from the fields through which they have cut. Erosion thus tends to modify natural drainage conditions. It increases the volume and velocity of run-off and is often an important factor in the severity of torrents and floods. An increase of run-off caused by soil erosion is followed by a reduction in the proportion of the rainfall which seeps into the soil and reaches streams by underground channels. This is reflected in lowered dry-weather flow of streams and rivers.

Siltation: One of the most serious consequences of erosion is the loading of streams with silt. A portion of this silt load is derived from the cutting of banks. The major portion, however, comes from sheet and gully erosion on the land. It is estimated that each year fully 1.5 billion tons of soil are moved from the cultivated fields of the country, a considerable portion of which reaches the streams and larger rivers. It is in large part the product of erosion on the land that forms the bars and other channel deposits and furnishes the silt that progressively fills many reservoirs, irrigation canals, and other water channels.

Social-economic consequences: Soil erosion has a far-reaching influence on community life, industrial development, and stability of population. The prosperity of rural communities depends on maintenance of the productive qualities of the land. Soil whose fertility has been reduced merely by the drain on natural plant food can be rehabilitated by fertilization and skillful tillage. The removal of soil by erosion represents a permanent loss to the capital resource of agriculture. Farm land passes progressively through stages of deterioration until it reaches the marginal and then the submarginal grade. During this process the standard of living of those dependent on the land is lowered progressively. There is an increase of farm tenantry, tax delinquency, bankruptcies, and land abandonment. Where many farms are affected the income of the whole community is lessened. There is a failure to maintain public institutions and public improvements, a progressive disintegration of the population, lowering of the morale of the people, increase of distress, and dependency on State or Federal relief.

The present day marginal land problem is due in part to the use of land which by its physical character or location is unfit for permanent agricultural activity. It is due in a great many sections to impairment or destruction of land by erosion. Erosion thus strikes at the very foundations of our rural civilization. It undermines the basis upon which hopes of future development of many communities and regions have been built. Continuance of unchecked soil erosion in many places inevitably means the necessity for population shifts which may be accompanied by a large amount of human suffering.

Methods of Erosion Control

Agricultural experts and others have for many years been developing practical measures of erosion control. It is recognized that complete prevention of erosion is impossible because there will always be some movement of the surface soil on all slopes. This can, however, be reduced to a relatively small amount by methods found by experience to be effective. The most important procedures in erosion control are as follows:

1. The conversion to forest or sod pasture or range, of areas too steep or otherwise unsuited for tillage;
2. terracing, to reduce the velocity of run-off, check erosion, and conserve moisture;
3. tiling, to reduce surplus surface water and improve underground drainage;
4. skillful tillage, including contour plowing, deep plowing, maintenance of sod strips and, of special importance, adequate fertilization;
5. use of close-grown crops, rotation of crops, strip-cropping, and use of winter-crop cover;
6. control of forest fires, especially for the protection of the litter and humus;
7. control of grazing of live stock on range, home pasture, and in the forest;
8. the checking of incipient gullying of fields by smoothing off or filling depressions and by placing brush or other obstacles at the more dangerous points to lessen the erosive action of the water. The checking of advanced gully erosion requires more radical measures, including the rectifying of the slopes of the banks, the construction of check dams, drainage and other works, and the planting of trees, shrubs, or other soil-holding vegetation;
9. special measures to protect caving banks in connection with river improvements;
10. measures specially adapted to prevent wind erosion, including the plowing of furrows (listers) at frequent intervals across the prevailing winds, mulching, and, where practicable, various methods commonly used in checking water erosion.

Need for Action

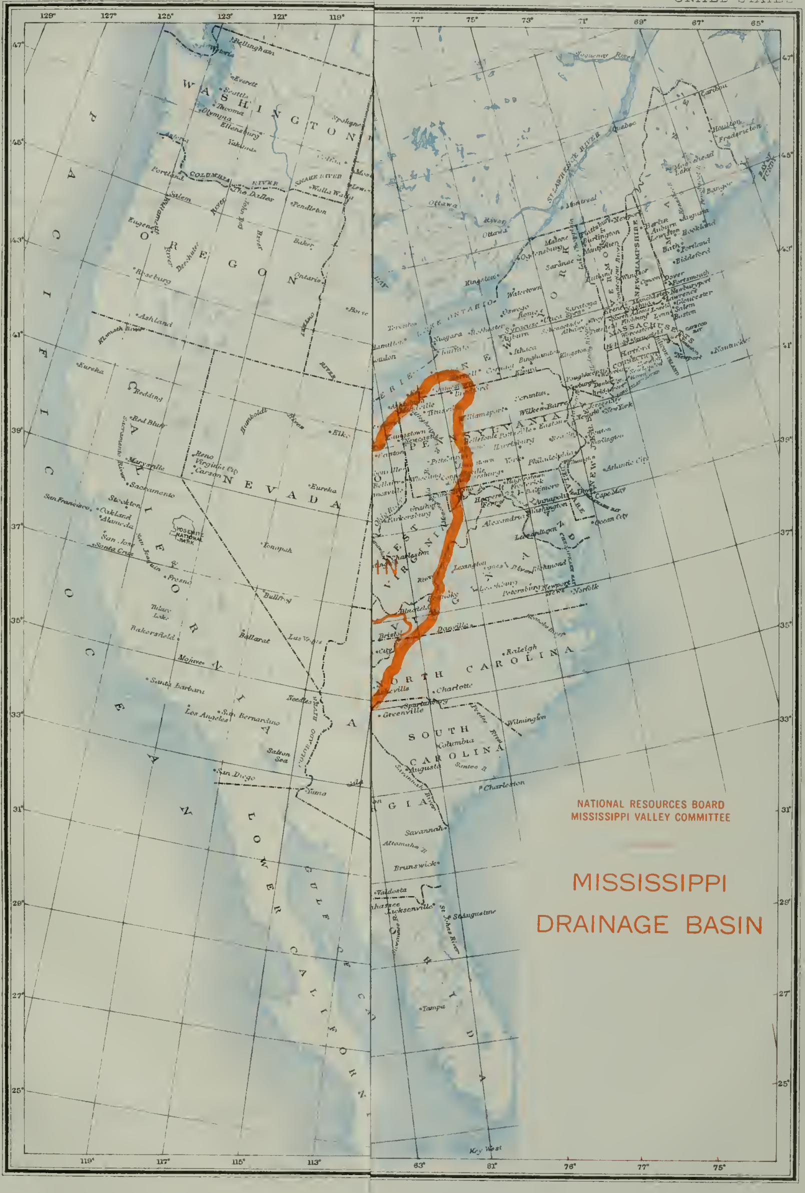
The problem of erosion involves the protection from serious and permanent injury of the soils of the country, upon which in large measure the life of the Nation depends. Mounting losses make it imperative to take immediate action which will bring into operation on a very wide scale and in a short time the measures of erosion control which experience has shown to be practical and effective.

BOOK III TOWARD SOLUTION

SECTION I

THE MISSISSIPPI VALLEY BASINS

UNITED STATES



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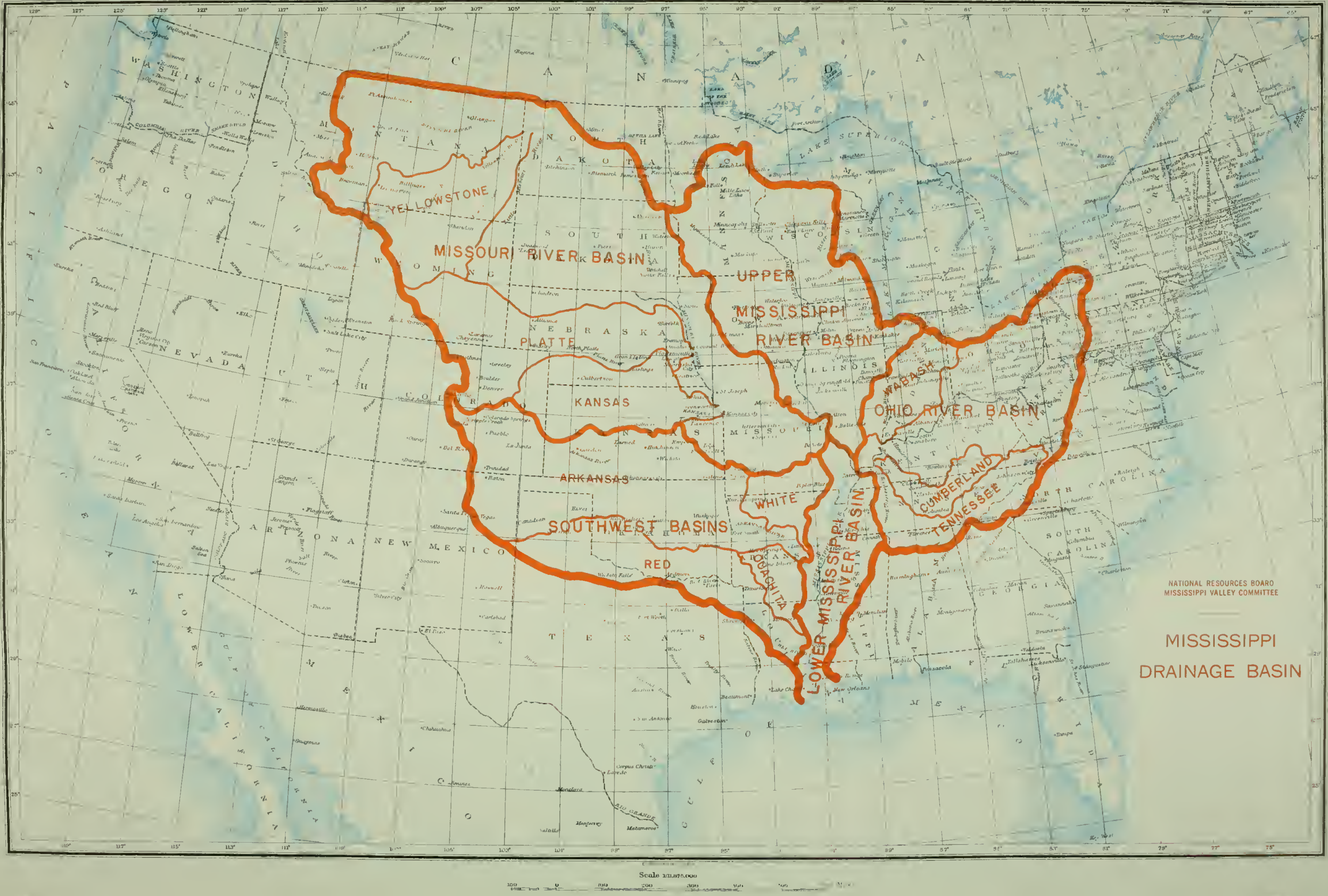
MISSISSIPPI DRAINAGE BASIN



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MISSISSIPPI DRAINAGE BASIN

THE UPPER MISSISSIPPI REGION

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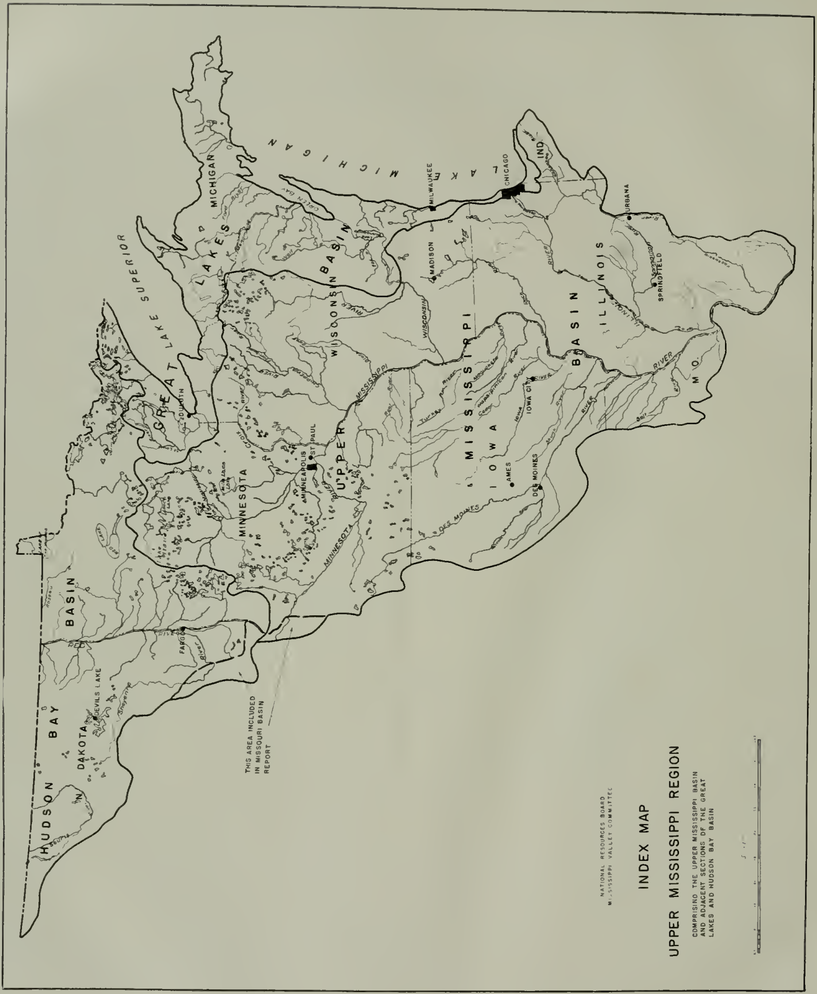
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UPPER MISSISSIPPI REGION
COMPRISING THE UPPER MISSISSIPPI BASIN AND ADJACENT SECTIONS OF THE GREAT LAKES AND HUDSON BAY BASIN
HUDSON BAY BASIN
GREAT LAKES BASIN
UPPER MISSISSIPPI BASIN
ILLINOIS BASIN
WISCONSIN
MINNESOTA
IOWA
ILLINOIS
MICHIGAN
IND.
MO.
N. DAKOTA
LAKE SUPERIOR
LAKE MICHIGAN
GREEN BAY
THIS AREA INCLUDED IN MISSOURI BASIN REPORT
DULUTH
ST. PAUL
MINNEAPOLIS
FARGO
DEVILS LAKE
MILWAUKEE
CHICAGO
MADISON
URBANA
SPRINGFIELD
IOWA CITY
AMES
DES MOINES
MISSISSIPPI
WISCONSIN RIVER
MINNESOTA RIVER
DES MOINES
RED RIVER
IOWA RIVER
ILLINOIS RIVER
ROCK RIVER
CEDAR RIVER
TURKEY RIVER
SOURIS
SHEYENNE
SALT
RIVER

I. The Region

1. *The River System and the Basin:* The Upper Mississippi Basin is that sector of the drainage area of the Mississippi River north of the junctions of the Missouri and Ohio rivers, not inclusive of the drainage areas of these two tributaries, each of which is itself a great system. The dominant river factor in this basin is the main stem of the Mississippi, which from its source in Lake Itasca to the junction of the Ohio has a length of 1,400 miles. The most important tributaries of this upper sector of the Mississippi are as follows: flowing from the northeast, the St. Croix, Chippewa, Black, Wisconsin, Rock, Illinois, and Kaskaskia rivers; flowing from the northwest, the Minnesota, Turkey, Maquoketa, Wapsipenicon, Iowa-Cedar, Skunk, and Des Moines rivers. For the purpose of this study there have been included with the Upper Mississippi basin two economically related sectors of contiguous basins; that part of the Great Lakes basin lying west of Lakes Michigan and Superior; and that part of the Hudson Bay basin within the United States, of which the Red River of the North is the central water feature. (See map facing this page.)

The Upper Mississippi drainage area is about 185,000 square miles, or 15 percent of the entire Mississippi drainage area, and the related Great Lakes and Hudson Bay drainage areas together about 95,000 square miles. The total is approximately 280,000 square miles.

2. *Cultural Status:* The area under consideration includes practically all of the states of Illinois, Wisconsin, and Minnesota, the eastern two-thirds of Iowa, somewhat more than the northeastern third of North Dakota, the Upper Peninsula of Michigan, corners of Missouri and Indiana, and a few square miles of South Dakota. In agriculture, mining, manufacture and commerce it is one of the most important regions of the United States. It has 9.6 percent of the area, and 12.8 percent (nearly 16,000,000) of the population, of the continental United States. The proportion of the land devoted to crops varies from 60 percent in Iowa to 37 percent in Minnesota; for the entire region it is 41.3 percent. It is a major producer of corn, wheat, barley, oats, hay, swine, cattle, and dairy products. Its farm buildings, implements, and machinery represent in value nearly one-quarter the total of the United States. Of its farms 17.3 percent have water piped to dwellings and 18.5 percent are lighted by electricity; 44.5 percent have radios, 65.6 percent telephones, and 95.2 percent automobiles. In mining the region accounts for 15 percent of the value of the production of the United States, and for over 80 percent of the tonnage of iron ore. The value of its diversified manufactured products in 1929 was $11,000,000,000, approximately 16 percent of the total for the United States. In commerce the Upper Mississippi Basin occupies a strategic position at the axis of east-west and north-south national transportation arteries. Chicago is the inland commercial metropolis of the Continent. Minneapolis-St. Paul and over the border of the basin, St. Louis and Kansas City—are gateways of transcontinental traffic, most of which crosses the basin.

Notwithstanding this general high economic culture of the region, the culture is not evenly distributed. There are many local areas within the region in which economic well-being is declining. The irritating stimuli of unfavorable local conditions, as well as the impact of general economic forces, have made this region a source of the national literature and of national movements of discontent.

3. *Absence of Pivotal Water Factors:* Water factors, reflecting here nature's niggardliness and there man's maladroit use of nature's generosity, have played a very considerable part in creating these numerous local problems. Yet no particular water factor plays a dramatic part. None of the rivers have their sources in mountain snows which in the spring pour widespread floods into valleys; there are no great rapids offering sites for Boulder or Wilson dams; erosion does not tear down banks and trees and rocks in masses. Like Lilliputs—apparently insignificant in the unit but significant in the aggregate—the water factors play their part inconspicuously, but on the whole with noteworthy influence. Instead of, like great floods, dealing an occasional destroying blow at economic security, they have in numerous places gradually woven their threads of influence over man's economic life in a manner which impairs its stability. However, before developing this theme further it is desirable to review the water characteristics of the region.

II. Physical, Especially Water, Factors

1. *Topography:* The topography of the region as a whole is fairly level, and the greater part of the State of Illinois, with adjacent sections of Iowa and Wisconsin, is one of the most nearly

level areas in the United States. A line drawn roughly from Des Moines, Iowa, to Ausable Point on Lake Superior divides the region into approximate halves, of which the southeastern half lies between the 500- and 1,000-foot contours, and the northwestern half between the 1,000- and 1,500-foot contours. There are small sections in northern Wisconsin, northeastern Minnesota, and north-central North Dakota where the 1,500-foot elevation is exceeded. Generally variation from the lower to the higher elevations is gradual, and there is no pronounced "fall line" from one level to another offering power sites. Although flashy, nowhere are the rivers extremely lively, and in their lower reaches particularly they are fairly sluggish most of the year.

This upper basin of the Mississippi system was the only one almost entirely covered during the ice age, and glacial action had several significant results in respect to water factors. Its leveling influence accounts for the absence of extremely lively rivers and power sites, and for the level land and the till and silty soils of the Illinois sector; and its morainic action accounts for the innumerable kettle holes and drift pockets of northwestern Wisconsin and northern Minnesota. These pockets became the sites of many thousands of fresh-water lakes, of which some 13,000 still remain. The dead lakes and some low lands in other parts of the basin have become swamps and marshes. The importance of these will be indicated later.

2. *Temperature and Rainfall:* The average summer temperature varies from 60 degrees in the extreme northern part to 75 degrees in southern Illinois, and the average winter temperature from 5 degrees in the extreme north to 35 degrees in the south. The growing season in the northern part of the region is 3.5 months, and in the southern part 6.5 months. The Great Lakes have an appreciable modifying influence on adjacent areas. Different combinations of these temperature factors, topography factors already noted, and rainfall factors to be noted, explain the predominance in Illinois and Iowa of the corn and livestock industries, in southern Minnesota and especially Wisconsin of dairying and mixed farming, and of spring wheat in the valley of the Red River of the North.

In respect to rainfall, the mean annual precipitation varies from 18 inches in the northwestern part of the region to 42 inches in the southwestern part; and the April-July precipitation from 10 inches in the northwestern part to 16 inches in the southeastern. Therefore nearly all the region lies within the humid belt and approximately 68 percent of precipitation occurs during the growing period of grains; but western Minnesota and North Dakota are located at the breaking point between favorable and unfavorable conditions of precipitation. (Map A.) This Red River sector is dependent for continuously successful agriculture on a nicety of balance between rainfall, run-off and the water table; a balance which nature does not maintain constantly. Even the greater part of the region may at times suffer from drought at critical seasons, as was the case during the growing season of 1934.

The records of rainfall over a long period are not adequate for generalization, but a comparison of data of the only relevant stations having long-time records (St. Louis, St. Paul, and Marietta, O.) suggests that there may be in this region an alternation between periods of lesser and periods of greater rainfall, showing a curve of some seventeen years between years of lowest and years of highest precipitation.

3. *Run-off, Floods, Erosion, and Low Water:* Approached from the point of view of destructive floods on the lower main stem of the Mississippi, the waters of this upper region do not contribute a run-off comparable with that of the Ohio, but of significance when coincident. When the melting snows of winter are combined with heavy spring rains, there is a flood flow of generally manageable proportions in the upper reaches of the main stem; and throughout most of the year the main river is in spots fairly strong and turbulent. The representative flood flow at Grafton, Ill., is 350,000 c.f.s., and the recorded maximum 450,000 c.f.s. Recent records at Keokuk, averaged over a five-year period, show that only 12 percent of the basin's precipitation, or 3.45 inches, appears in the river at that point. The run-off varies from 0.41 inch in the Minnesota River basin to 7.91 inches (25 percent of precipitation) in the Black River basin. The latter figure indicates that in some places the run-off is of local importance. It is locally important in the two respects that it causes local floods which are destructive of crops on the areas affected (Map D), and is the cause of serious erosion in various places, especially in an irregular area on both sides of the Mississippi from the Minnesota River to the Rock, and in northeastern Missouri, southeastern Iowa, and southwestern Illinois (Map E). On the other hand, the low-water flows of the tributaries, and consequently of the main stem below the headwaters, create in many places serious

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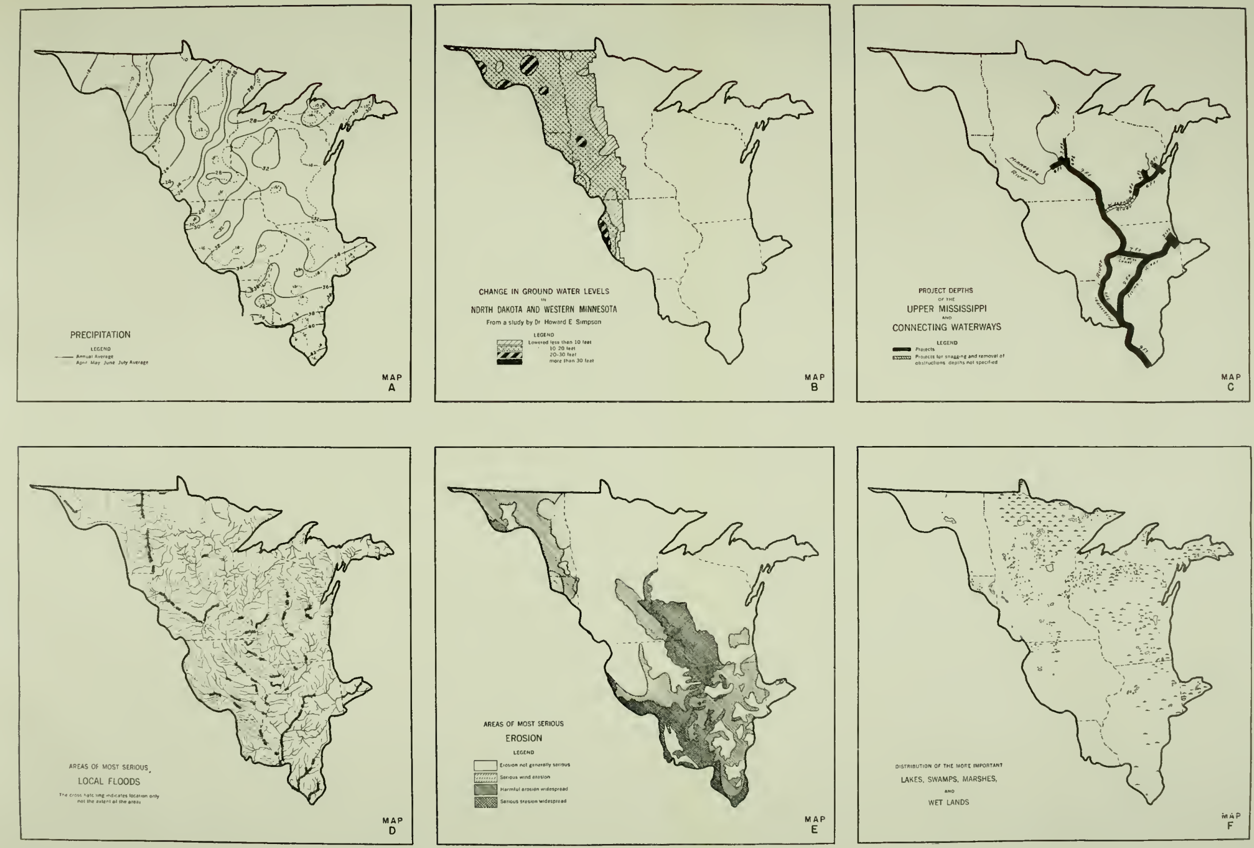
PRECIPITATION
LEGEND
Annual Average
April May June July Average
MAP A
CHANGE IN GROUND WATER LEVELS
IN
NORTH DAKOTA AND WESTERN MINNESOTA
From a study by Dr Howard E Simpson
LEGEND
Lowered less than 10 feet
10 20 feet
20-30 feet
more than 30 feet
MAP B
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OF THE
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AND
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LEGEND
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Projects for snagging and removal of obstructions depths not specified
Minnesota River
MAP C
AREAS OF MOST SERIOUS
LOCAL FLOODS
The cross hatching indicates location only not the extent of the areas
MAP D
AREAS OF MOST SERIOUS
EROSION
LEGEND
Erosion not generally serious
Serious wind erosion
Harmful erosion widespread
Serious erosion widespread
MAP E
DISTRIBUTION OF THE MORE IMPORTANT
LAKES, SWAMPS, MARSHES,
AND
WET LANDS
MAP F

WATER FACTORS OF THE UPPER MISSISSIPPI REGION

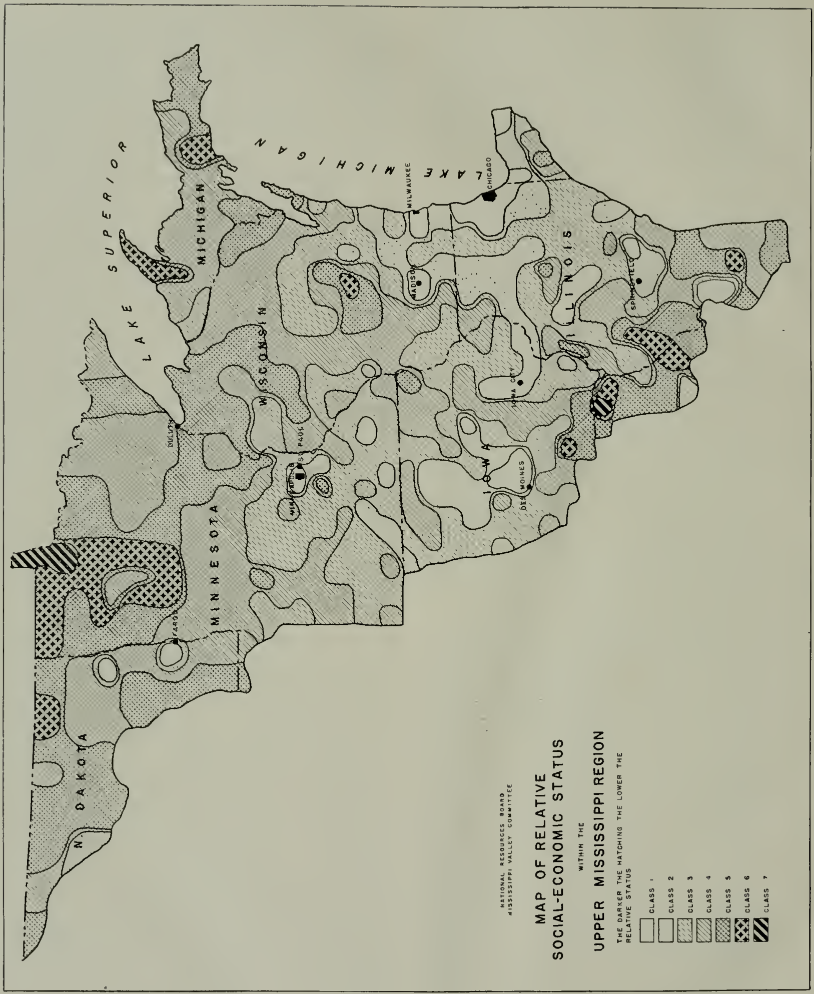
problems of water supply and sanitation. This is indicated by their combined influence on the main stem at Grafton, Ill., where the average flow is 100,000 c.f.s. and the representative low-water flow is only 30,000 c.f.s. In a season of unusually deficient precipitation the Red River of the North and its tributaries may become practically dry.

4. *The Ground-water Level:* Data of strictly scientific validity concerning changes in the ground-water level are not available, because controlled systematic measurements have not been made. A special study of the critical area between the humid and arid belts along the 100-degree meridian indicates a depletion which averages 13 feet in Minnesota, 16 feet in North Dakota, and 17 feet in South Dakota. This is serious for an agriculture dependent on a balance between this and other water factors (Map B).

5. *Lakes, Swamps, and Marshes:* One of the most interesting and important aspects of the relation of water factors to culture is found in the numerous lakes, swamps, and marshes—hummocky cedar and flat tamrack swamps, cranberry and peat bogs, muskegs, and "wetlands" (Map F). The lakes have already become important for recreation—the income of the summer-resort business is third in rank in Minnesota and fourth in Wisconsin—and offer a basis for a planned development of a great playground for the north central states. The swamps, marshes, and lowlands are elements of nature to which man has not yet learned how properly to adjust; and his mistaken assumption that any land, including swamps and marshes when drained, is suitable for productive occupation, has lead to many unwise investments in drainage projects and ill-fated ventures in agriculture. Approximately 21 percent of the improved land in the four states of Illinois, Iowa, Wisconsin, and Minnesota is in drainage enterprises. Much of it is fertile and very productive. Low income from those parts which permit only submarginal agriculture explains the reason for many of the problem areas of the region. Most of the swamp lands should be restored to their proper use—as forests like those which once covered 58 percent of the Upper Mississippi basin, or as refuges for wild game. However, for these uses they should not be completely restored, for in their original condition they were not all suitable even for forests and game. Most of the drained marshes might well be restored to marsh hay lands.

6. *Navigation:* In its original condition the Upper Mississippi was navigable at certain seasons throughout its entire length, and before the advent of railroads was the most economical route to the northwest. River traffic reached its peak in the decade 1850–60, when it is said 1,100 steamboats plied the upper river. From then on the river traffic was unable to meet the competition of developing railroads; in part because of inadequate depth and obstructions, but chiefly because the rivers, unlike the railroads, were at right angles to the direction of traffic. The Congress of 1878 approved a project providing for a 4.5-foot channel; and in 1907 the present project, which first provided for a 6-foot channel on the main stem above St. Louis, and lesser channels on tributaries, but was modified in 1932 to provide a 9-foot channel on the main stem. The Federal expenditures on projects of the Upper Mississippi system above the mouth of the Ohio to June 1934 were: on the main stem, $104,300,000, and on tributaries and connections $21,750,000, a total of $126,050,000, not including $40,000,000 for maintenance and operation. The estimated cost of completion on the present project as it now stands is: for main stem, $91,300,000, additional expenditures on tributaries and connections being estimated as negligible. The maximum traffic since continuous records were begun on the stretch between St. Paul and the mouth of the Missouri was 4.5 million tons in 1903. The minimum was in 1916 with 500,000 tons, between which point and 1,000,000 tons it has since varied. The great decline has been the result mainly of diminishing traffic in logs and lumber.

It is not possible by any calculations of business accounting to discover an economic justification for the vast expenditures on the projected improvement of these waterways; especially from the prevailing viewpoint of self-liquidation, but also even from the viewpoint of complete coverage of costs of maintenance and operation. It is the more impossible when consideration is given to the fact that diversion of grain traffic from railroads, which is included in present calculations, is quite likely to be checkmated by the highly probable development of through water traffic from the Great Lakes by way of the St. Lawrence river to the Atlantic. On the other hand, there is nothing in past experience which permits us to envisage the total situation of productivity and exchange of commodities between the upper, central, and lower reaches


NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE
MAP OF RELATIVE
SOCIAL-ECONOMIC STATUS
WITHIN THE
UPPER MISSISSIPPI REGION
THE DARKER THE HATCHING THE LOWER THE RELATIVE STATUS
CLASS 1
CLASS 2
CLASS 3
CLASS 4
CLASS 5
CLASS 6
CLASS 7
LAKE SUPERIOR
LAKE MICHIGAN
MICHIGAN
WISCONSIN
MINNESOTA
IOWA
ILLINOIS
N. DAKOTA
DULUTH
ST. PAUL
MINNEAPOLIS
FARGO
MILWAUKEE
CHICAGO
MADISON
IOWA CITY
DES MOINES
SPRINGFIELD

of the Mississippi basin, and connected regions, when there shall exist these great arteries of water transport of adequate depth throughout the entire valley and connected with the Great Lakes. Especially is this true in view of the fact that present studies of planned utilization of natural resources indicate the need of a comprehensive program of new allocations of land to more varied uses, which will inevitably include renewal of traffic in heavy commodities; and in view further of indications of a more decentralized and widely distributed industry.

7. *Power:* The Mississippi and its upper basin tributaries generally have their sources in a flat highland, flow through lakes with broad outlets and through broad valleys, and therefore offer no opportunity to create artificial storage of any consequence, or for the construction of dams of any height. On the whole the development of hydro power must depend upon the occasional stretches of rivers which offer suitable heads. There are very few places where more than a 30-foot head could be obtained. Paper mills established early in Wisconsin and Minnesota, naturally made use of the best power sites. Other industries have preempted additional sites, and all the best hydroelectric sites in the Mississippi basin itself are now developed. It should be noted, however, that there exist in the adjacent sectors of the Great Lakes and Hudson Bay basins a number of high head sites, now remote from markets, which under some new over-all organization of the power industry might be linked into a grid reaching adequate markets.

The most comprehensive survey of possible water-power sites in the region is presented in the "308 Reports" of the Corps of Engineers. (House Document 308, 69th Congress, 1st Session.) A summary follows:

State	Number of sites	Installed kilowatt capacity	Estimated cost
Illinois	12	66, 700	$15, 534, 000
Iowa	68	183, 100	48, 940, 000
Minnesota	53	194, 970	46, 016, 000
Wisconsin	72	382, 880	122, 316, 000
	205	827, 650	232, 806, 000

While the total of indicated possible installed capacity is impressive, it must be observed that many projects are based on as little as 20 percent time flow of streams. Thus it is evident that the cost per k.w. of the development for prime power available is much higher than the cost per kw. of installed capacity. It is not likely that many of the possibilities listed will be built under present conditions in the industry, as under such conditions fuel-burning plants are more economical. On the other hand, in a more highly integrated power industry utilizing all plants to capacity, a considerable number of these hydro sites might economically be absorbed into the system. It is pertinent to observe that the average k.w.-hr. consumption of farm customers in Iowa, Wisconsin, and Minnesota is only some 65 percent of the average farm consumption of the entire United States (California excluded), and that the farm service rate in Iowa is the second highest, in Minnesota the third highest, and in Wisconsin the eighth highest in the United States. Calculations indicate that it would be reasonable to assume a requirement of something like a 45 percent additional capacity in the next twenty years, with a k.w.-hr. increase of some 62 percent.

III. Representative Water Problems as Disclosed by Area Studies

1. *Map of Relative Economic Status:* There has been noted an absence of outstanding characteristics on which a study of the waters of the region might be pivoted. This has stimulated a special approach to the problem. If localities presenting relative economic instability can be identified, a cue would be provided for discovery of unfavorable forces, including the water factors. Accordingly an isopleth map of the economic status of various parts of the region was constructed. (See map facing this page.[1])

This graphical analysis has facilitated identification of problem areas, discovery and appraisal of the influence of water factors on economic conditions and trends, and particularly of the influence of such non-dramatic aspects of water as rainfall and drought, subsurface storage and the water table, local floods, erosion, and lakes, swamps, marshes, and drainage. For instance, the map shows a relatively low economic status in the Keweenaw Peninsula of Michigan. Inspection shows that decline of the copper industry and a resort to subsistence farming are the vital factors, and that water does not play an important part. Also the declining economic status of that section of the coal region of Illinois lying southeast of the mouth of the Missouri is not to be explained in terms of the influence of water factors so much as in terms of competition of oil and gas piped from the southwest basins. On the other hand, inspection of the area indicated by the dark spot in the northwestern corner of Indiana discloses a water problem typical of the entire region. This upper valley of the Kankakee River was once a marsh land without agriculture. Promotion of drainage projects induced settlement and establishment of agriculture. But because drainage operations were inadequate, local floods still destroy crops—during the decade 1920–30, two years out of three. Either the drainage development should have been better planned and more completely executed, or the area should have been left to nature's disposition for the wiser uses of ducks and other wild-life.

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[1] A note concerning the construction of this map is in order. Each of the 371 counties in the region was rated on a scale of one to eight in respect to twenty-four characteristics indicative of economic trends during the decade 1920-30, prior to the influence of depression. A population change group contained two series; a farm abandonment group four series; a gross productivity group two series; and a net-income-standard-of-living group, sixteen series. The separate ratings in respect to these twenty-four series were then weighted and combined into one composite rating for each county. The map is a plotting of the region into areas consisting of counties of equal rating. The map has stood the test of usefulness for the purpose for which it was constructed. It is not offered however, as giving a precise indication of the economic status of any particular county. Because of the incompleteness of some and scarcity of other data, refinements of statistical method which would establish a reasonable assurance of accuracy in respect to any particular detail were not possible.

Below are considered the more important classes of water problems, with illustrations of each that are by no means exhaustive.

2. *Drainage of Infertile Lands:* The most successful development of agriculture in northern Minnesota east of the Red River Valley is along the basin of the Rainy River where that river and the tributaries afford natural drainage. Southwest, south, and southeast of the Lake of the Woods, however, lies an extensive area characterized by a large peat bog. This area was once covered by glacial Lake Agassiz, and absence of marked topographical features is indicated by the diversified direction of the natural drainage; the northern and eastern section draining to the Hudson Bay by way of the Rainy River, and the western part to the Hudson Bay by way of Red Lake and the Red River of the North. Its southern boundary is the low watershed of the Upper Mississippi drainage area. Much of the region was once covered by extensive forests; but after removal of the commercially valuable timber, and under the stimulus of war expansion, extensive drainage operations were initiated and agricultural settlement stimulated.

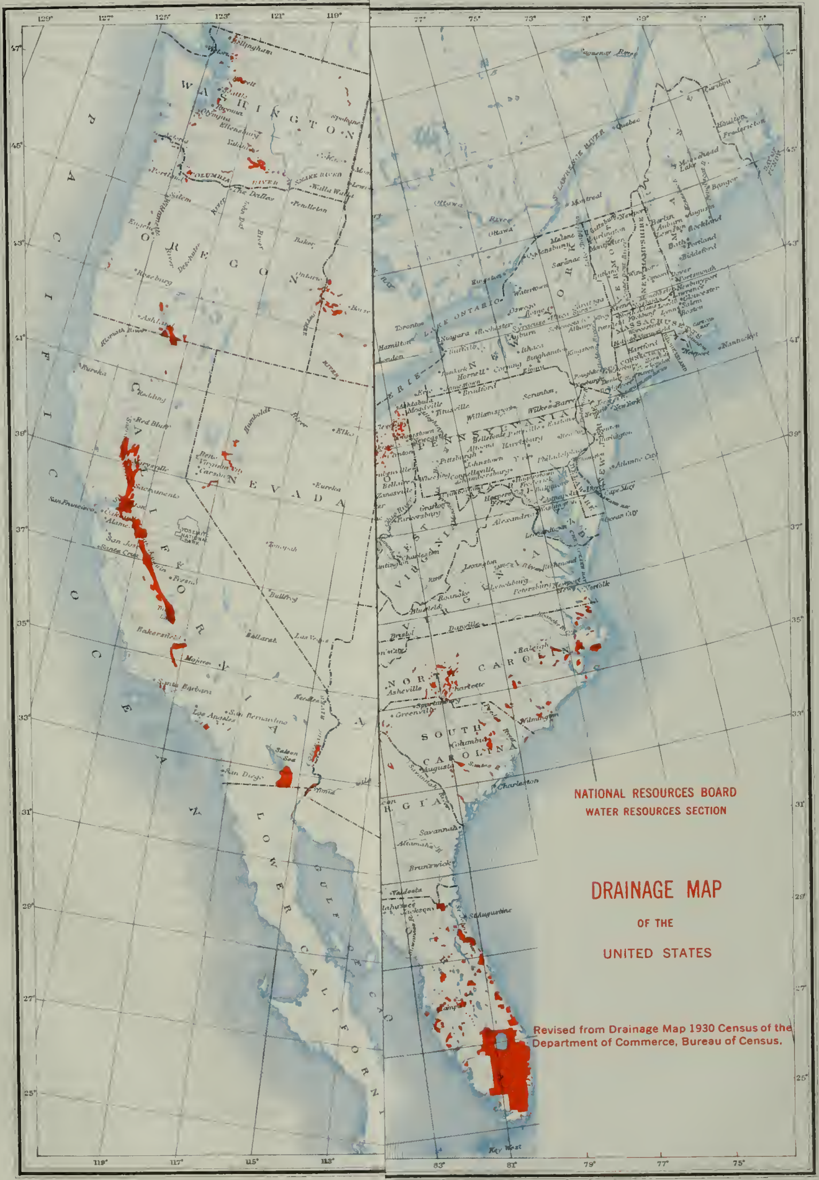
Drainage has failed to convert the region to agriculture. Not only has drainage itself proved difficult, but the peat soils after drainage are inherently unproductive because lacking in essential minerals. They are also susceptible to killing frosts in the growing season and to destructive fires in the dry season. These fires destroy the humus covering, usually increase the need for more drainage, and make agriculture the more difficult.

The agricultural settlers are left stranded. Land is rapidly reverting to the State through tax delinquency and the failure of drainage districts, upon some of which the state has assumed the bonded indebtedness. The region was intended by nature for forests. In many of the swamps, black spruce and northern white cedar can be produced, and on the higher ground, pines and hardwood. The few lakes, especially the Lake of the Woods, offer distinctive recreational possibilities; but the greater part is suitable only for recreational game, including not only bird life but also big game such as deer, elk, and moose, which could be successfully propagated. For such uses, however, the region should not be permitted to revert completely to its original state of excessive swampiness, but to a state of moderate drainage designed for the purpose.

Another region of similar characteristics is found in central Wisconsin. As in northern Minnesota, swampy peat and sandy soils predominate. A flat, moderate plateau, formerly in rainy seasons it drained both into Lake Michigan by way of Lake Winnebago, and into the Mississippi by way of the Wisconsin River. Flood control works have destroyed this characteristic. In its original state the region was a natural storage reservoir and regulator of stream flow for the Wisconsin River.

The economic history of this region is patterned along the same lines as that of the Minnesota region described above. After removal of the better grades of timber, drainage operations were undertaken over some 600 square miles and agriculture penetrated the region. The natural nonproductiveness of the soil, fire hazards from dry peat, meager income, and the financial burden of the drainage operations, have combined to bring tax delinquency, bankruptcy, and abandonment.

Agriculture may well be continued in easily drained localities where better grades of soil are found in sufficient concentration, and hay crops may be profitable on some of the less easily drained areas; but even such agriculture to be economically practicable would probably have to be supplemented by part-time employment in forests and in game management, for both of which the region is peculiarly suitable. Here also there should not be a return to the original excessively swampy state, but to a carefully conceived and integrated program of moderate drainage adapted to a combination of supplemental agriculture, increased reservoir



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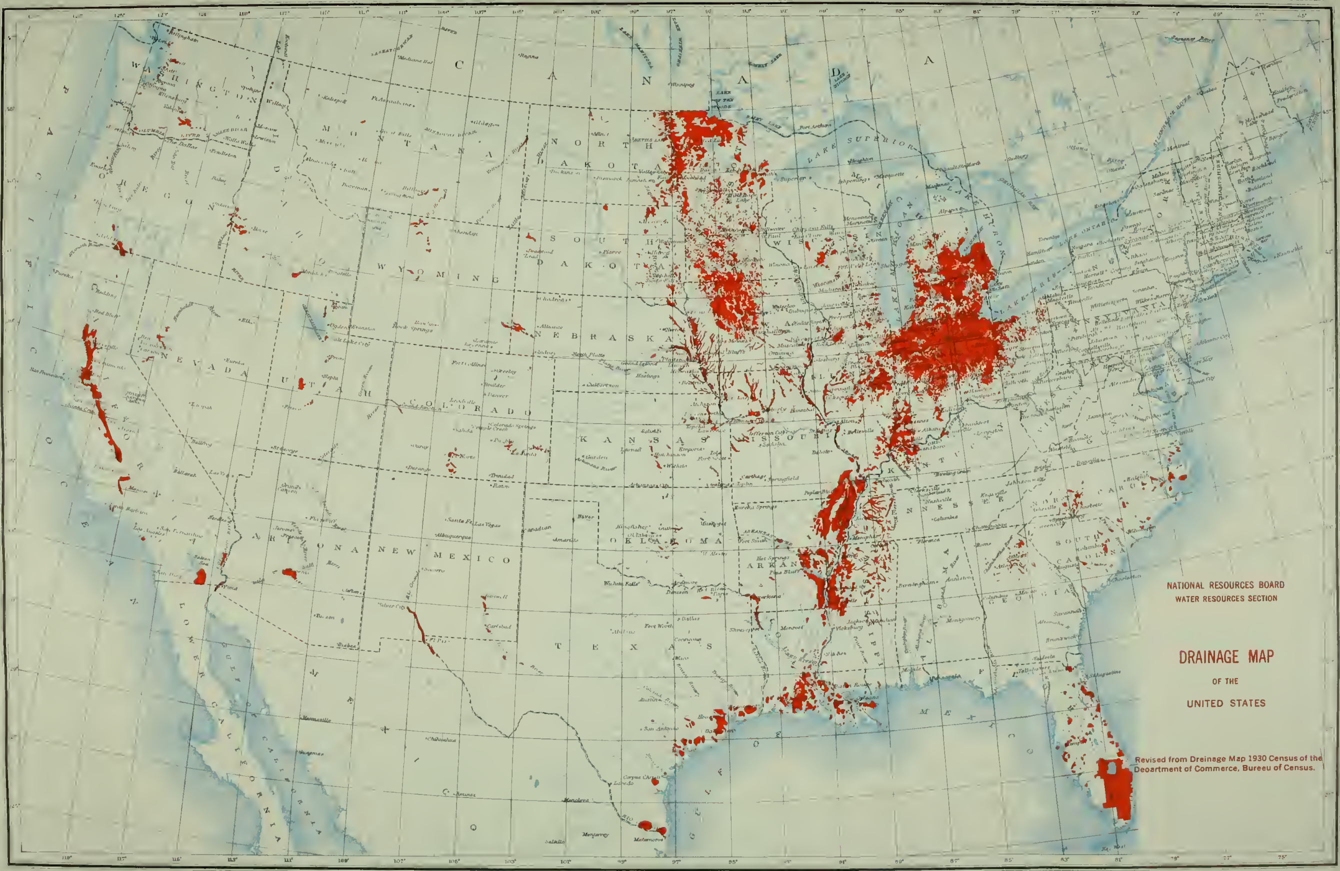
DRAINAGE MAP
OF THE
UNITED STATES

Revised from Drainage Map 1930 Census of the Department of Commerce, Bureau of Census.

Land in drainage enterprises shown in red



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DRAINAGE MAP
OF THE
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Revised from Drainage Map 1930 Census of the Department of Commerce, Bureau of Census.

Land in drainage enterprises shown in red

Scale 1:11,875,000

100 0 100 200 300 400 500 600 Miles

capacity to regulate the the Wisconsin stream flow, reforestation, and recreational game reserves.

3. *Drainage of Fertile Lands:* The Red River Valley of Minnesota and North Dakota extends from thirty to fifty miles on both sides of the river. The valley is today a flat surface of fertile, alluvial soil left by Lake Agassiz. This broad, unforested, prairie plain was rapidly developed during the period of railroad and agricultural expansion following the Civil War. The agricultural development of the valley, however, has been handicapped because of the difficulty of controlling or adjusting to its water factors. Paradoxical as it may seem, the water problem is a composite of deficient rainfall, poor drainage, depleted water table, and intermittent droughts.

Because of the flatness of the land and the presence of barely perceptible depressions and low swells, the region is lacking in adequate natural drainage. The Red River and its tributaries are shallow, winding streams with poorly defined bottom lands. Although the land immediately bordering these streams is fairly well drained naturally, artificial drainage is essential on most of the land in the valley, because one of the most extensive soil types in the valley is a black silty clay or clay-loam soil which is easily cultivated when dry, but sticky and tenacious when wet. Artificial drainage, however, has its difficulties. Outlets are difficult to find for large ditches, and depressions are frequently lower than the shallow, lateral ditches. With continuous cultivation, depletion of the natural humus is causing the soil to become more compact and more difficult to drain. Tile drainage has not been extensively employed because the flatness of the land makes it difficult to find outlets. In addition, in the more compact soils drains must be laid near the surface, which limits the area benefited and increases the number of drains required. While extensive ditching is improving the drainage, the lack of adequate drainage, even in this region of limited rainfall, remains one of the most important of the water problems affecting land use.

There is in the valley a mean annual precipitation of about twenty inches. On the whole, its distribution is such that serious droughts do not occur frequently, as the greater part of the rainfall occurs in the late spring and early summer; but the amount of the rainfall and its distribution creates a relatively narrow zone of productive balance, with risks threatening when either an excess or deficiency occurs. An increase in rainfall of a relatively few inches will delay seeding and make the more poorly drained sections too wet for cultivation until too late for a crop to mature, the growing season being short, averaging between 110 and 130 days. On the other hand, decrease in rainfall curtails crop yields, for the sandy and gravelly loam soils are particularly dry in droughty years. In years of exceptional drought, depletion of the water table is making more difficult adequate provision for the needs of the live stock with which the valley abounds.

Altogether, there is presented here one of the nicest problems of planning a land use that expresses a proper balance between a number of water factors. Humidity to the east and aridity to the west are controlling factors, but here the one is not severe enough and the other is not beneficent enough to control. The problem is one of adjusting to the most favorable relations among several factors.

4. *Water Supply, Pollution and Sanitation:* The problem of the quality of the waters is especially important in the Upper Mississippi region, because it has concentrations of population and of industry which would tax any water system, especially one where the streams generally do not carry a large volume. Every type of pollution of water and every type of demand for pure water is found in the region. The cities of varying size, of course, require pure water for drinking purposes. Nearly all industries require it for condensing purposes, and the numerous food industries in the region for reasons determined by their processes. It is necessary to the livestock industry, especially in the dairy region. It is essential to recreation which makes so much of lakes. On the other hand, many of these institutions which demand quality in water also pollute it, especially the cities with their sewage, and the pulp, creamery, canning, chemical and similar industries with their industrial wastes. Because in this region nearly every river is the site of cities or industries discharging waste, and because few of the tributaries of the upper Mississippi carry much volume of water, the problem of pure water and sanitation has become a pressing one. Even though the City of Chicago can procure abundance of satisfactory water for domestic and industrial use from Lake Michigan, it cannot return its sewage and waste to that lake; and its problem of disposal of sewage and waste is well known. One or another combination of factors creates a problem of pure water or pollution, or both,

in nearly every section of the Upper Mississippi basin.

a. The Red River of the North is an outstanding example: The river is used generally by necessity—if financial inability to create substitute situations be considered a compulsion—both as a source of drinking water and of sewage and other waste disposal by Wahpeton, Fargo, Moorhead, Grand Forks, and lesser cities and villages. Yet the rainfall and run-off are such that in periods of low water the river becomes an open sewer, and it has been known in the winter to freeze to the bottom. The Red River at Grand Forks drains an area of 25,000 square miles; although in April 1897, it reached a volume of 43,000 c.f.s., in October 1932 it diminished to 13 c.f.s. It approaches the former volume less frequently than the latter.

Such a problem is usually considered municipal; but here it is regional. The cities are unable individually or jointly to solve the problem. They are essential to the valley; and the ground water, generally becoming depleted, also is essential to the valley. A draft on the subsurface deposits in quantity sufficient for solution of the domestic water and pollution problem would intensify the agricultural problem. Here again we perceive a problem of balance among factors; a problem which can be solved only as part of some comprehensive regional plan.

b. Southern Illinois: Southern Illinois presents a contrast, in that the problem does not center about one principal stream. Here are numerous small streams, of which the Kaskaskia is the largest. Cities and villages are dependent largely on water from surface streams, and the rural sections on shallow wells, both sources being in many instances within seepage distance of barnyards and other unsanitary outbuildings. The results are reflected in health statistics; in Jackson and Randolph counties the typhoid death rate in 1932 was 19.6 and 13.6 per 100,000, respectively, as compared with 1.6 and 0.7 for the entire States of Illinois and of Wisconsin. Similar high rates are characteristic of dysentery and other gastro-intestinal diseases caused by contaminated water supplies. Here again is more than a local problem from the point of view of local ability to plan, finance, and carry through what must be a comprehensive plan.

c. Chicago and the Twin Cities: These cities afford illustrations of the sanitary problems of great industrial cities, and of the influence of such cities on the sanitary problems of other communities, especially in level areas. The problems of these cities have been the subject of many hearings and reports, and of litigation, and will not be detailed here. Attention is called, however, to their illustration of a principle which must be more fully recognized and established in practice generally; that with respect to pollution and sanitation, corrective and preventive action must first be applied at headwaters and extended downstream in one comprehensive plan. To improve casually from the mouths of streams upward increases beyond reason the total cost of solution of the problem for an area. The individual increments of expenditure applied in a hit and miss manner might well be beyond individual capacities to pay, whereas they might be borne as parts of a regional project. And the psychology of "What's the use?" prevails where communities are expected to go it alone.

d. Decentralized industrial waste: On many of the smaller streams of the region are located pulp mills and small food manufacturing plants which require pure water. Too frequently they discharge manufacturing chemicals and waste into the very streams from which they have drawn their pure water, and create problems of sanitation for the cities and villages, and even the farmers, downstream. This may come to be the major pollution problem of the future. The large cities, and individual plants in large cities, are being compelled by public opinion to provide sewage and waste disposal facilities; but such improvements may be in part neutralized by industrial plants and other communities. Although the City of Peoria has recently completed a sewage treatment plant, there is an industrial concern still pouring waste into the river equivalent to ten times the volume of the raw sewage of the city.

What stimulus to solution of the water supply and pollution problem can come from consideration of it as more than a local problem, and from Federal contributions to it on that basis, is illustrated by the constructive influence of P.W.A. In this Upper Mississippi region P.W.A. has made loans and grants, and otherwise given assistance in constructing sewage disposal and other works, to 107 municipalities whose total expenditures amount to nearly $80,000,000; and 127 municipalities are receiving funds for municipal waterworks costing nearly $16,000,000.

5. *Erosion:* Water erosion in some stage of development is found in all parts of the region where it is not prevented by forests and other vegetative cover, and where swamps or wet lands do not predominate. Generally its

harmful influence is not obvious, but in two areas it is recognized as serious.

a. As the six glacial sheets advanced and receded they left one small area untouched—an area stretching from southwestern Wisconsin to northeastern Iowa, and from southeastern Minnesota to northwestern Illinois. Unaffected by glacial action, and cut by the Mississippi, Wisconsin and the smaller streams, the area is relatively rugged. It is in large part covered by loess soils varying in depth from three to twenty feet, and on the valley bottoms by alluvial soils. Fine in texture and lacking the resisting powers of stratified residual soils, these soils are highly erodable, especially after spring thaws following deep freezing have loosened them; and erosion progresses rapidly from the sheet to the gully stage. The high productivity of the soils has induced the extension of tilling up the slopes to an extent beyond the ordinary in such a topography, with the result that in the absence of preventive measures 75 percent of the farms are seriously impaired by erosive action of the run-off.

b. A second area of even more serious erosion is found in southeastern Iowa and northeastern Missouri, where the topography is rolling and in many places rugged. The soils are fairly productive and have been good crop lands, the principal crops being corn, wheat, and oats. The combination of rolling terrain, the loose and solvent nature of the soils, and an average annual rainfall of about 34 inches which in some years reaches 54 inches—and in some storms a fall of four to six inches in twenty-four hours—has brought the area to an advanced stage of erosion and gullying. In some places all of the top soil has disappeared, and fully 50 percent of the farms have been seriously affected.

In each of these seriously eroded areas the economic and general cultural life of the inhabitants has been subjected to progressive decline, and both are examples of a challenge to planning for a more rational organization of land use, and for agricultural practices suitable for the conditions.

6. *Local Floods:* Floods of a catastrophic nature do not occur in the Upper Mississippi region. They are precluded by the dominant physical characteristics already described. Nevertheless, damaging floods of local significance are frequent. (Map D.)

a. Natural floods occur in the principal tributaries, which flow through fairly well-defined, mostly cultivated, alluvial valleys varying from one-half to four miles in width.

Of annual occurrence are the early spring floods, especially in the northern part. Here heavy rainfall and melting snows find an easy run-off on frozen ground. These floods may be damaging to property where ice jams form in the rivers, which is not frequent; but on the whole they are not serious because planting has not begun.

More serious are the late spring or summer floods of the more southern part which follow heavy, sometimes torrential, rainfalls. These are known locally as "gully-washers." A fall of four to six inches in twenty-four hours is not uncommon, and eight points in Iowa have recorded over ten inches in twenty-four hours. The force of these rains packs the soil and increases run-off. In the more poorly drained and wet valleys particularly, the resultant local floods may retard planting beyond the season critical for a good crop. Those that occur later in the year may drown growing crops.

Such floods occur chiefly in the valleys of the Red River of the North, the Minnesota, the Wolf-Fox, the Illinois, and the Kaskaskia. Danger of severe floods on the upper main stem of the Mississippi and on the Wisconsin has been almost eliminated by regulatory works.

Records do not permit an estimate of the aggregate damages from the scattered floods. They take the form of loss of crops, and of damage to highways, railroads, bridges, and rights-of-way, and occasionally to buildings. Rarely are cities and villages completely flooded. Local projects for levees and regulation of channels are affording some, although generally inadequate, relief. In the agricultural stretches of the valleys opinion is divided, many farmers conceding it a fair deal to swap an occasional crop for alluvial fertilization.

b. Artificial Floods. Recurrent floods resulting from the failure of inadequate or improperly constructed levees protecting low-lying cultivated lands, are most serious on the Illinois River, and the damage in some years has amounted to millions of dollars. This river has an unusually wide flood plain for its size, because it is the successor of a greater river which drained some of the territory now drained by the Great Lakes and the St. Lawrence. The alluvial soils of these flood plains, which are highly fertile, have been protected by levees and are devoted to a productive agriculture. These levees have not been constructed in accordance with a comprehensive plan, but separately by numerous small levee and drainage districts.

The average annual precipitation of the Illinois basin is about 35 inches, one-fourth of which appears as run-off; but in some years the precipitation has amounted to 60 inches. In such years the levees fail to confine the run-off and create the most serious flood problem of the entire Upper Mississippi region. The run-off range of the Illinois River in its natural state has varied from 1,000 c.f.s. to 120,000 c.f.s., and since 1848 the basin run-off has been increased by waters diverted from Lake Michigan for sanitation purposes by Chicago. A decree of the U.S. Supreme Court limits this diversion at present to 6,500 c.f.s., which by 1938 must be reduced to 1,500 c.f.s.

Below La Salle the Illinois Valley has an average width of 2.5 miles. Below Peoria about half of the 340,000 acres of overflow area has been leveed, the floodway being from 1,200 to 2,500 feet wide. The height of floods and the rate of flow—also the hazards—have been increased by the reduced cross-section of the river. The three major floods of the past decade—1922, 1926, and 1927—overflowed half the protected, cultivated land. The average annual loss of recent years is estimated to be $2,243,000.

State authorities agree with the Corps of Engineers that the most rational method of flood control in this valley involves setting back levees to increase the floodway widths, raising and strengthening levees, and relinquishment of the remaining bottom lands to reforestation, bird refuges, and reservoirs for stream control. Here Nature's ways have been modified by unplanned works of man in a way not advantageous to man in the long run; now engineering and economic experience indicate the need of a planned retreat towards Nature's arrangements.

7. *Drainage Restoration and Reconstruction:* The Illinois basin is again selected to illustrate a special water problem; one which is characteristic also of certain headwater areas in Iowa and southern Minnesota. Many tributaries of the Illinois have their sources in flat, wet lands whose fertility has induced drainage operations to make them usable.

This is accomplished by tiling which feeds into open ditches. Drainage and cultivation have been under way so long that the effectiveness of the drains are beginning to show evidence of impairment by siltation. Increase of tenancy with its rapid turnover of occupancy has caused loss of many records and recollections of the location of the tile drains. Therefore, the region is approaching the problem of redrainage, involving policies as to what lands should be redrained and what type of draining should be employed. Of even greater importance as a challenge and an opportunity, will be consideration of the policy whether waters should be rushed, as in the past, directly to the river, or whether they should be put to new uses by retention, where topography permits, in decentralized lakes and ponds, or by gates in the drainage ditches, and perhaps where practicable made the bases of individual or community supplementary farm irrigation.

IV. Creative Opportunities

Intelligent reconstruction, implied in the types of water problems which have been discussed, is of course creative. But reconstruction is positively creative when it goes beyond neutralization of harmful influences and sets up progressively beneficial influences. There is opportunity for such creativeness in the Upper Mississippi region, and the beginnings have been made.

1. *Land Use—Zoning:* All the states in the region under consideration now have more or less effective planning commissions. Especially noteworthy is the progress made in the states of Wisconsin and Minnesota prior to the establishment of formal planning agencies.

This progress represents a fairly well developed public opinion, as is indicated by Wisconsin's leadership in legislation permitting the classifying and zoning of rural lands within counties. This legislation was stimulated primarily perhaps by the problem of financing educational, highway, and other social services for marginal and submarginal rural communities unable to maintain them for themselves; but it is likewise valued as the basis for a generally more rational policy of land use. A more rational policy of land use includes conspicuously in this region an intelligent program of utilization of or adjustment to water factors.

2. *Recreation:* The more than thirteen thousand lakes and the numerous small streams of the northern part of the region provide the elements for further development of one of the great playgrounds of the nation. In it are possible two contrasting types of recreational water facilities:

a. The lake regions of northern Wisconsin and central Minnesota already provide recreation of the type preferred by those who desire seclusion and the pleasures of waters and woods, yet prefer planned and regulated recreational communities which make available the simpler—and in some instances the sophisticated—collective conveniences and services, and the provisioning afforded by neighboring producers of meat and vegetable foods. The planning here is one of preventing, on the one hand, exclusive possession by a few owners, and on the other hand, overcrowding, annoying, commercialized recreational activities that do not fit, and inappropriate use generally.

b. In marked contrast to the lake country are such areas as the Arrowhead Country of northeastern Minnesota. Here the topography is rugged and studded with outcropping crags having a scanty covering of soils; and there are wild forests and numerous small lakes and small streams. In it may be developed and preserved those characteristics of wild nature which makes Maine a favorite haunt of the hunters and fishermen of the Atlantic Coast—those who revel in life of log camps and transportation by pack and canoe.

3. *Forests and Game Refuges:* The second obvious field of opportunity—in this instance of adjustment to, rather than utilization of, water factors—is in respect to rehabilitation of the forests and establishment of game refuges. Both have relations to a program of development of recreational facilities noted above; but in addition there are vast areas whose highest use would be expressed in restoration of commercial timber, and development and management of the reforested lands in accordance with best forestry principles and practice, so that they would eventually become a continuing source of annual income to the region.

4. *Intensive Inventory of Waters:* Miscellaneous constructive utilizations of water resources are potential in an intensive quantitative and qualitative inventory of the waters of the region. Highly developed in agriculture and manufacture, the region may receive in the future a wide range of demands for water with respect both to quality and quantity. The waters of this region, for instance, have an extraordinary wide range of variation in hardness. This region can and should set an example of how a water inventory may be made really useful. Every stream, lake, or pond, and the different levels of the ground water, should be labeled in respect to their chemical, temperature, vegetative and similar characteristics, the quantity available, and the uses for which they are best suited. With such data maps could be constructed to indicate locations most suitable for restoration of fishing, for domestic supply reservoirs, and for manufacturing enterprises preferring particular kinds and quantities of water. Such an inventory would be perhaps the most useful single device for incorporating water resources into a general program of development.

V. Policy and Projects

In the absence of outstanding and pivotal water factors, the Upper Mississippi Valley offers, with one exception, no defined project of magnitude having an obvious Federal interest.

1. *Navigation:* The exception to which reference has just been made is completion of the present project for a nine-foot channel to the Twin Cities referred to in Section II. While an economic justification for it cannot be computed by any standard business accounting formula, the Committee does not recommend its discontinuance. There are two reasons for this. First, it is part of a program which already has been authorized by the Congress; second, there is a strong argument that the main stem of the great river should be made one navigation unit from its mouth to these regionally important headwater cities and natural navigation terminals; and, incidentally, that the river system should be tied into the Great Lakes system.

2. *Miscellaneous Projects:* There has been brought to the attention of the Committee a number of projects in this region which evidence cannot at present qualify as presenting any large amount of Federal interest, meritorious as they appear to be from the local point of view. Among them are the Red Lake dam (flood control and storage for dry seasons), the Lake Traverse-Boise de Sioux dam (flood control and storage for cities), the Mouse River dam (flood control, pure water and sanitation), the Lac Qui Parle dam (flood control and storage), and the Whestone River-Big Stone Lake Reservoir diversion (flood control, pure water for municipal use and recreational facilities). Such projects appear to be of importance from the local and regional point of view, and may merit moderate but not exceptional Federal contributions. It is the Committee's judgment, however, that projects such as these are of the type that should be appraised, not separately, but as elements in a comprehensive regional plan.

3. *The Project Par Excellence:* As project par excellence, however—for this region certainly, and possible for the entire United States—the Committee recommends that immediate steps be taken to promote the development of comprehensive regional planning in a manner in which state, interstate and Federal participation are integrated. In no other

basin in the country does it happen that there exists a basis for such a step equivalent to the one offered by the fact that practically all the states of this basin are already inspired by the planning concept and already have created appropriate local instruments. Because of the nature and variety of the water factors which have been here reviewed, and because of the initiative already taken by the states, regional planning for this basin, with respect to research, definition of projects and execution, would undoubtedly be primarily an affair of the states; but there are interstate problems and other perceptible opportunities for integration of Federal and interstate interests and efforts, in accordance with the principles and the technique presented in the section on Relations of Interests and the section on Planning.

As Aldo Leopold of the University of Wisconsin has observed, "Civilization is not an enslavement of a stable and constant earth." Man does not *conquer* the earth, but attempts to enter into an harmonious relationship with it. His response in this relationship largely determines the duration of his particular civilization. The absence of pivotal water factors in the Upper Mississippi region permits attention to the fact that a great variety of valuable factors offers opportunity and challenges ability to design a relationship which promises a high plane of human welfare.

THE OHIO BASIN

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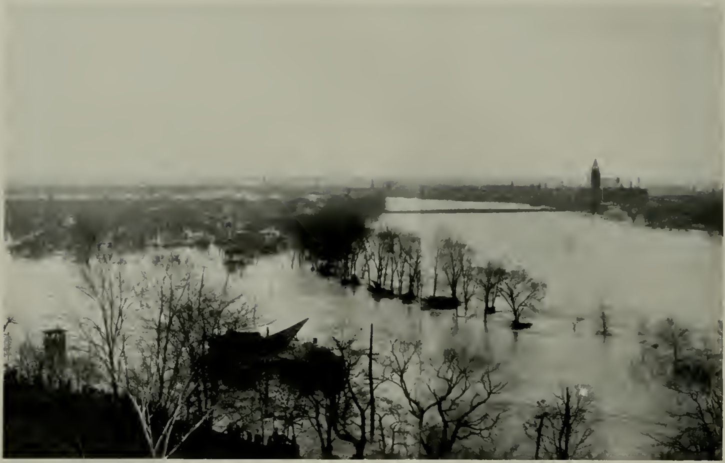
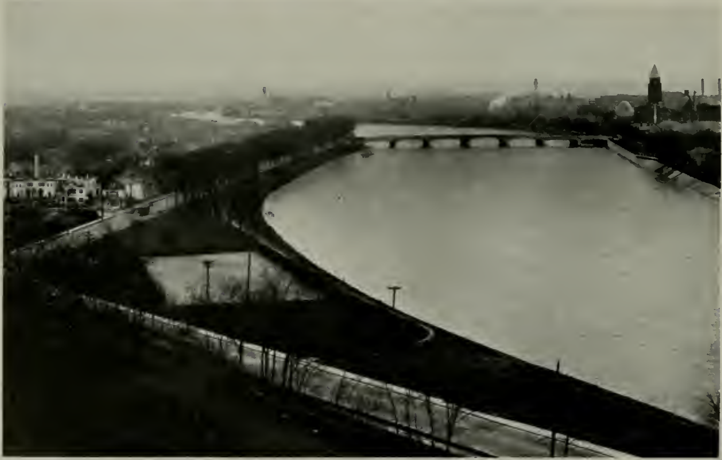




Above—An uncontrolled river on a rampage—Looking upstream, the normal river channel is at the right. The flooded area extends all the way back to the left; wreckage in foreground; flooded homes and bridge in middle distance; at the right is a main business section of the city flooded 12 feet deep.

Below—The same river (in flood) under control—The stucco apartment house in foreground at left is new but the house at its right is the same one shown in the upper picture. The buildings at the right of the bridge may be identified in both pictures. Flood control reservoirs above the city provide this control.

I. Natural Features

The Ohio River System: The Ohio River is the largest, longest, and most important tributary entering the Mississippi from the east. Measured from its source in the glacial hills of southwestern New York to its junction with the Mississippi River at Cairo, Illinois, the Ohio River has a length of about 1,300 miles equivalent to two-thirds of the distance between Chicago and Los Angeles.

In general, the Ohio River System has a normal treelike pattern. However, the Tennessee and the Cumberland rivers, reaching far to the South where they drain most of Tennessee, northern Alabama, and the western slope of the high southern Blue Ridge Mountains, join the Ohio just above its mouth and seem more like independent river systems than tributaries.

The Ohio River System contributes to the Mississippi a minimum flow of about 25,000 cu. ft. per second, a maximum of about 1,500,000 cu. ft. per second, and under ordinary conditions of neither flood nor drought, a flow of about 250,000 to 300,000 cu. ft. per second, or more than one-half of the corresponding flow carried by the "Father of Waters", just below Cairo. Throughout most of the year the Ohio and its major tributaries have abundant water for navigation, power, and domestic and industrial uses.

During periods of unusually dry weather the Ohio gets lower than is desirable for optimum usefulness. Then, contamination of the water supply and increased difficulty of navigation are two major inconveniences. Fortunately, however, the Ohio itself never has so little water that navigation is seriously affected, or that the cities and towns along its banks are deprived of domestic and industrial water.

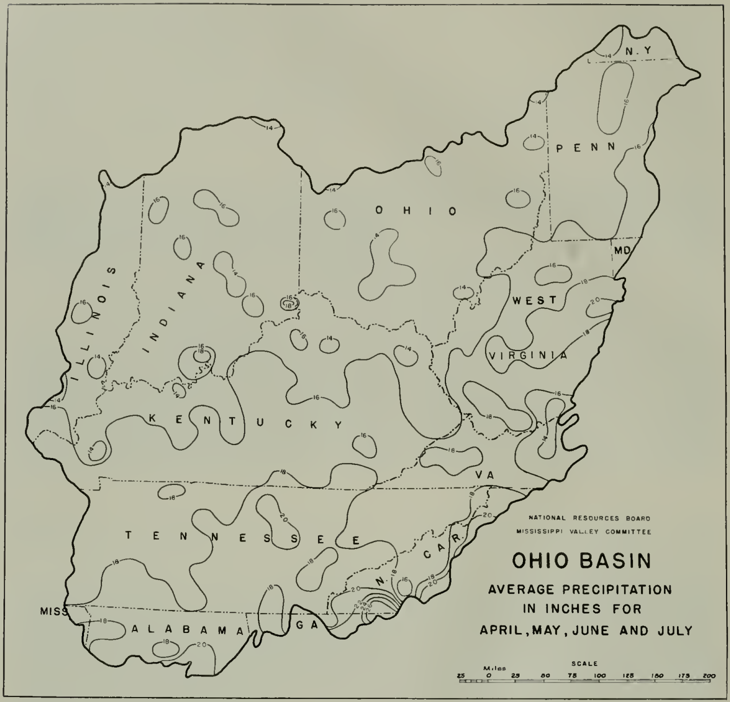
Floods of average intensity are common in the Ohio River System, but are relatively unimportant. At irregular but long intervals—once in 25 to 100 years on an average—this system experiences terrific floods which inundate large areas normally considered safe from damage. Flood conditions on the Ohio have a profound effect on the lower Mississippi River. During flood periods the Ohio often contributes two thirds (1,000,000 to 1,500,000 cu. ft. of water per second) of the total flood water carried by the Mississippi just below Cairo.

The Basin—Size: Almost one sixth of the area tributary to the Mississippi River lies within the Ohio Basin. The 204,000 sq. miles comprising this Basin would more than contain Italy, Austria, Hungary, and Belgium. Parts of fourteen States are drained by the Ohio and its tributaries, but no State is entirely within the Ohio Basin.

Physical Characteristics: Three major physical divisions characterize the Ohio Basin. Rough hills and mountains of the Appalachian Highland dominate the east; lower hills of the Interior Low Plateaus occupy the southwest; and gently sloping glacial lowlands of the Interior Plains are found in the northwest and north. A considerable variety of topography is found in this part of the Appalachian Highland. The Blue Ridge Province in eastern Tennessee and western North Carolina has the highest mountain in the eastern half of the United States. Just west of the Blue Ridge in eastern Tennessee and southwestern Virginia is the narrow Valley and Ridge Province. Long, symmetrical, parallel ridges give this Province a unique appearance. Most streams flow in fairly straight lines along the valleys between these folded ridges. Next to the west, and trending in the same northeast-southwest direction, lie the irregular, varied Appalachian Plateaus. During the long ages since these plateaus were uplifted, streams have been actively cutting and enlarging valleys. In eastern Tennessee, eastern Kentucky, West Virginia, and southern Pennsylvania, where the old plateau was high, the present topography is mountainous in aspect. Farther north in Pennsylvania and southern New York the surface is hilly but less rugged.

In elevation and relief the Interior Low Plateaus which cover the southwestern part of the Ohio Basin in central Kentucky and Tennessee are intermediate between the Appalachian Highland and the Interior Plains. Streams throughout the Low Plateaus generally are swift and occupy comparatively steep-sided, narrow valleys. In the Lexington Plain and the Nashville Basin, however, the surface is more level and the Cumberland and the Kentucky rivers flow slowly.

Western Ohio, central Indiana, and southeastern Illinois comprise a distinctive part of the Ohio Basin. This area, a part of the Interior Plains, differs strikingly from the hilly and mountainous eastern and southern parts of the Basin. Natural conditions here are so well suited to agriculture that this area, despite its dominant urban population, is the Ohio Valley's leading farming region. The eastern



Rainfall map for the Ohio Basin.

third of the famous "Corn Belt" occupies most of that part of the Basin north of the Ohio River.

Soils: Practically all soils in the Basin are of the light colored, leached type characteristic of forest areas. The silty glacial loams of the northern plain are least seriously leached because they are newer than the residual soils of the south and east. Deep silty loams also are found in the limestone areas of the Lexington Plain, the Nashville Basin, and the Valley of East Tennessee. In the hill and mountain country, by contrast, soils are washed down slopes almost as fast as they are formed. Alluvial soils of great depth and fertility occur in narrow bands along the flood plains of the Ohio River up to Wheeling and along the lower reaches of the Wabash, the Miami, the Scioto, the Tennessee, and the Cumberland Rivers.

Precipitation: Normal annual precipitation in the Basin ranges from 35 inches to slightly more than 50 inches. The Northern District, including that area adjacent to and north of the Ohio River, receives from 35 to 40 inches in east central Illinois, central Indiana, and Ohio. Southeastern Illinois, southern Indiana, northern Kentucky, and northwestern West Virginia usually get from 40 to 45 inches. Even more humid conditions prevail in the Southern District. Precipitation in hilly southern Kentucky, central Tennessee, and southern West Virginia amounts to 45 to 50 inches, while the Blue Ridge Mountains in westernmost North Carolina get over 60 inches.

Unfortunately for the users of water, few years have "normal" or "average" precipitation. The maximum recorded precipitation in the Ohio Basin ranges from 50 inches in eastern Illinois to 111 inches in the southwestern mountains. Minimum extremes also have a patchy distribution, but in the Northern District the general range is from 25 to 30 inches, while in the Southern District it is from 30 to 35 inches. As little as 20 inches of rain and snow have fallen in eastern Illinois.

Agriculture, a major industry in the Basin, largely depends on the quantity of rainfall during the April-July crop-growing season. Average conditions for this period show a general range of from 14 to 16 inches in the Northern District, and from 16 to 18 inches in the Southern District. This precipitation is adequate for most crops, including corn. During the driest year on record, however, the agricultural plains of the Northern District received only about half of their normal early summer precipitation. In spite of these occasional dry periods, serious rainfall deficiency is comparatively rare.

Natural Vegetation: Tall prairie grass was the natural vegetation of interstream areas in the upper Wabash Basin in eastern Illinois and west central Indiana. All other sections of the Ohio Basin, even the famous Blue Grass region, were originally covered by forests.

Forests: The Ohio Basin is situated in the heart of a great belt of hardwood forests once unexcelled in any other temperate region. The trees of these primeval forests were distinctive because of their number, large size, commercial utility, rapid growth, and vigorous reproductive powers. Several diversified forest types are represented: (1) the spruce-fir association of the highest elevation, (2) the oak-hickory in the southern plateau area, (3) the beech-maple of the northwestern plains, and (4) various lowland types along major watercourses.

At present approximately 38 percent of the Ohio Basin land area is classed as forest, about ten percent of which has been so devastated that it produces little or nothing of even potential value. In the entire Basin the standing timber large enough for the saw probably aggregates about 40 to 50 billion feet. This is less than the amount of lumber used in this country during one year.

Few regions possess such favorable natural conditions for forest restoration and, giving full consideration to all other uses, there will always remain a large proportion of the Basin's area better suited to forests than to other types of land utilization.

Other Natural Resources: The natural resources of the Ohio Basin characterize it as a logical center for agriculture and industry. Climatic conditions are favorable. The dependable rainfall is reflected in a generally adequate water supply, which may be rated as one of the Basin's most valuable natural resources. However, water is only one of the many valuable resources that have stamped the Basin as a mining and manufacturing center. Bituminous coal is present in great abundance and at widely separated points. Building stone, sand and gravel, glass and foundry sand, clay deposits, and most of the fluorspar produced in the United States are found in the Basin. In addition, there are within the Ohio Valley, or close by, large quantities of iron and copper ores, lead, zinc, bauxite, sulphur, gypsum, petroleum, salt, timber. Such assets indicate that mining and manufacturing always will be outstanding occupations in the Ohio Basin.

Considering the stable character of agriculture and manufacturing in this territory, the obvious conclusion is that here, if anywhere, exists an opportunity under most favorable circumstances for development of cooperation in these two fields.

Table *1* lists the production and use of a few more important natural resources indicating the relation which Ohio Basin production bears to that of the United States; also the approximate distribution of these materials in (1) the Ohio Basin, (2) the Mississippi Basin, (3) the United States. In this connection it is interesting to note that the population of the Ohio Basin is about 14 percent of that of the whole country, and the corresponding percentage of area is about 7 percent.

TABLE 1.—*Ohio Basin, production and use of natural resources*

Item	Production in United States in 1929		Production in Ohio Basin in 1929		Percent of United States production in Ohio Basin	Percent of Ohio Basin production used (estimated)			
	Estimated tons	Estimated value	Estimated tons	Estimated value		In Ohio Basin	In Mississippi Basin	In United States	All other (includin export)
Coal [1]	535,000,000	$953,000,000	350,000,000	$665,000,000	70	50–60	60–70	97	3–5
Limestone	100,000,000	115,000,000	27,000,000	31,000,000	27	40	80	99	1
Other stones	40,000,000	89,000,000	35,000,000	50,000,000	56	40	60	100	0
Sand and gravel	222,000,000	133,000,000	36,000,000	30,000,000	23	95	95	100	0
Clays	4,347,020	14,800,000	1,200,000	3,100,000	21	100	100	100	0
Fluorspar	140,000	2,700,000	133,000	2,565,000	95	30	35	100	0
Natural gas	[2] [3] 1,943,000,000,000	[3] 416,100,000	[2] 335,000,000,000	58,000,000	14	80–90	80–90	100	0
Salt	8,500,000	27,000,000	1,250,000	3,000,000	11	95	95	100	0
Lumber	[4] 36,886,000	993,000,000	[4] 2,500,000	89 000,000	9	95	100	100	0

[1] These figures are for bituminous coal. In 1929, 73,828,195 tons of anthracite were produced and valued at $385,643,000. Of this probably 260,000 tons, worth $681,000, was produced in Ohio Basin.

[2] Cubic feet.

[3] 1930.

[4] Thousand feet board measure.

I. Cultural Features

Agriculture: Approximately 53 percent of the area of the Ohio Basin is in crops or pasture, and the rainfall is so dependable that a serious crop failure is of rare occurrence. Of the cultivated area, roughly 40,000,000 acres, about 30 percent is in corn, 20 percent in hay, about 20 percent in wheat and oats and other grains, 2 percent in tobacco, and the remainder in miscellaneous crops and garden truck. A fair annual value of Ohio Basin crops is approximately $1,000,000,000 and another billion would represent the annual value of livestock and dairy products.

Striking contrasts in pattern and in crops differentiate farming areas in the Northern District from those in the Southern. Broad rolling fields on the northern plain produce corn, oats, hay, garden truck, poultry, beef, and dairy products in commercial quantities. In the scattered lowlands of the Southern District commercial farmers raise tobacco and cotton, but small-scale production of corn, hogs, and vegetables for local consumption is common in the extensive hill areas.

With a farm population of some 5,000,000 people, it is estimated that no less than 1,500,000 are directly engaged in agricultural pursuits. Assuming the dangers of soil erosion will be recognized here as elsewhere and that proper means will be generally adopted to secure tangible results in soil-erosion control, the continuation of successful agricultural operations here seems assured.

Land Ownership: Virtually all land in the Basin is privately owned. No unappropriated public lands remain, and there are comparatively few National Forests or other reservations. From the standpoint of private land ownership two districts may be recognized—(1) the Northern District, including that territory bordering and north of the Ohio River, and (2) the Southern District, including most of the hill and mountain country.

The Northern District is about 60 percent urban and 40 percent rural. More than half the city dwellers own their residences, and about three-quarters of the farm operators hold title to their land. Between 1920 and 1930 there was a marked decrease in the proportion of tenant farmers. One hundred acres is the average farm size.

Markedly different conditions characterize the Southern District. Here the population is about 70 percent rural and 30 percent urban. Far less than half the comparatively few city folk own their homes, and only about 60 percent of farm operators are also owners. Farm tenancy here showed a gain of about 7 percent between 1920 and 1930. Farms average about 80 acres, but many of them, especially those in the hill country, have considerable areas not suited for cropping.

Manufactures: During 1929 the 22,000 or more factories in the Basin employed about 1,250,000 persons and produced goods valued at $9,000,000,000.

As would be expected, iron and steel products head the list with a value of more than a billion dollars, approximately one-third of the entire production of the United States in that classification. Rubber products showed a value of well over $300,000,000, motor vehicles and accessories were valued at some $400,000,000, foundries and machine shops produced nearly $400,000,000 worth of output, railroad cars and repairs ran close to $300,000,000, and electrical machinery was worth $250,000,000 to $300,000,000. Meat products, paper, printing and publishing, tobacco products, knit goods, furniture are also important industries. Diversification of manufactured products in this region is so wide that there are few classifications listed in the Census of Manufactures not represented to an important degree in the output of Ohio Basin factories. This very diversification makes for stability of these manufacturing industries. The Basin includes the center of manufactures of the country as well as the centers of population and of consumption. A complete reversal of trends and procedures would be necessary to justify any doubt as to the industrial future of this region.

Table 2 lists a few of the more important manufacturing classifications in the Ohio Basin with values of products for the year 1929, relation of output to that of the country as a whole, and approximate distribution of these products (1) in the Ohio Basin, (2) in the Mississippi Basin, and (3) within the United States. This tabulation alone indicates the importance and stability of the Ohio Basin as a manufacturing region.

TABLE 2.—*Ohio Basin, production and use of manufactured products*

	Production in United States in 1929		Production in Ohio Basin in 1929		Percent of United States production in Ohio Basin	Percent of Ohio Basin production used (estimated)			
	Estimated tons	Estimated value	Estimated tons	Estimated value		In Ohio Basin	In Mississippi Basin	In United States	All other (including export)
Iron and steel products:									
Steel ingots and casting	[1] 56,435,000	[2] $3,365,000,000	[1] 30,000,000	[2] $1,250,000,000	[3] 53 37	27	49	98	2
Rolled products	[1] 41,059,000		[1] 23,000,000		[3] 56				
Motor vehicles, etc.	(4)	5,360,000,000	(4)	410,000,000	8	29	50	99	1
Foundry and machine shops	(4)	2,791,000,000	(4)	380,000,000	14	32	55	98	2
Railroad cars, repairs, etc.	(4)	1,184,000,000	(4)	262,000,000	22	25	50	99	1
Electric machinery	(4)	2,300,000,000	(4)	270,000,000	12	30	55	95	5
Rubber products	(4)	1,107,000,000	(4)	310,000,000	28	20	40	96	4
Meat products	7,600,000	3,435,000,000	680,000	275,000,000	8	100	100	100	0
Printing and publishing	(4)	1,738,000,000	(4)	183,000,000	11	40	80	99	1
Furniture, etc.	(4)	948,000,000	(4)	141,000,000	15	40	95	99	1
Knit goods	(4)	899,000,000	(4)	146,000,000	16	85	99	99	1
Tobacco products	(4)	1,246,000,000	(4)	190,000,000	15	20	40	97	3

[1] Gross tons of 2,240 pounds.
[2] Estimated value of all iron and steel products.
[3] Based on tonnages. Other figures based on values.
[4] Not applicable.

Transportation: No large region in the United States can boast better or more varied transportation facilities than those serving the Ohio Basin. Railroads, highways, and waterways all have been developed to a high stage of efficiency. Because of this condition there is in this region an unusual opportunity for the coordination of various transportation media.

Railroads: Railroads, the basic American transportation agency, serve all of the more important sections of the Basin. In the prosperous and productive Northern District every city, town, and farm is on or near at least one railroad. Main lines and branches are so close together and run in such a variety of directions that they cover this District like a net. A reasonable number of rail lines serve the important centers in the Southern District.

Both through and local freight are handled in tremendous quantities by railroads serving the Ohio Basin. Much of the heavy traffic between the Atlantic Seaboard and the Middle West and West crosses this territory. A considerable quantity of manufactured goods from industrial centers on the Great Lakes also crosses the Basin on its way to the agricultural South.

Highways: Highways, of course, are much more numerous in the Ohio Basin than are railroads. Splendid surfaced roads criss-cross the relatively level Northern District. Practically every farm in this area has an automobile, so even the less important roads are kept in good condition. Less adequate road systems are characteristic of the Southern District. Here state and Federal appropriations maintain satisfactory highways between major centers of population. In less prosperous hill counties, by contrast, roads commonly are poorly graded, and usually are in need of repair.

Motor-truck traffic is of unusual significance in the Ohio Basin. The closely spaced industrial centers of the Northern District produce much short-haul business ideally suited to motor transportation. Although trucks handle far less tonnage in the Southern District, they here perform a valuable social function. No other means of transportation can so efficiently deliver supplies to the more isolated part of the hill country.

Waterways: For more than a century the Ohio River System has ranked as one of our major inland waterways. In addition to the Ohio proper, numerous tributaries have been improved for navigation at a cost of some $240,000,000. The project depth for the Ohio is nine feet; that for the tributaries now averages about six feet, but the more important ones are being improved to offer facilities comparable with those on the main stream.

Modern demand for speed has driven most of the picturesque old steam-packets off the river and their package freight to the railroads. Private carriers—largely coal and steel companies—now transport more than 95 percent of the total commerce on the Ohio River. Most of this traffic moves over only small sections of the available waterway. However, the freight carried by the entire Ohio River System in 1929 was 40,000,000 tons, and the yearly ton-mileage, in a good year, reaches a total of over 3,000,000,000.

Population: At present the estimated population of the entire Ohio Basin is about 17,000,000. Both the United States and the Mississippi Valley as a whole have an average population density of about 40 per square mile, but the Ohio Basin, in 1930, had an average population density of 85 per square mile.

Growth: For many decades the population of this region has shown a steady, normal type of increase. In 1900 the Ohio Basin had about 12,250,000 inhabitants; by 1910 this had increased to 13,250,000; in 1920, partly as a result of the war-time industrial boom, the total rose to 15,500,000, and during the ten years between 1920 and 1930 the total was raised to about 17,000,000.

Distribution: No large areas with scanty population are found in the Ohio Basin. Except for a few scattered patches, chiefly in hills and mountains, all of this region has a population density of more than 25 per square mile. Roughly, two-thirds of the total population live in the urban, industrial Northern District, and, for the whole Basin, about the same proportion lives in cities and towns. The largest area of dense population is in and around Pittsburgh, but other chief cities also are centers of close settlement. Major coal fields in southern West Virginia and eastern Kentucky constitute the only densely inhabited hill areas. Certain especially favorable agricultural regions have more than 50 people per square mile, but ordinary farm areas range from 25 to 35.

Trends: The Ohio Basin is one of the most broadly developed and most stable areas in the entire United States. Here there is little evidence of the ebb and flow characteristic of the western edge of the Mississippi Valley. Between 1920 and 1930, however, two major trends can be recognized in the movement of population. All of the many larger cities of the region and the coal-mining areas of eastern Kentucky and southern West Virginia show large increases (from 15 to 75 percent) in number of inhabitants. Most agricultural counties, by contrast, registered either comparatively small gains or actual losses. Such movements reflect the urban lure during a period of industrial overemphasis. In spite of these trends, few sections of the country have shown fewer population movements of significance.

An abrupt decline in the rate of population increase for the country as a whole makes it unwise to use past figures as a basis for predictions. It seems probable, however, that the era of rapid city growth is about over, and that agricultural areas, especially those near industrial centers, and those best suited for general farming, should show definite increases in number of inhabitants. Future population changes probably will be the result mainly of shifts prompted by climatic or other similar advantages, favorable living conditions, lower costs of production and distribution, or a desire to take advantage of equitable taxation systems or other governmental efficiencies.

Standards of Living: Considered as a group, the Ohio Basin people enjoy a standard of living equal to or slightly above the national average. As in the case of land ownership, however, the Basin falls into two Districts—a Northern District and a Southern District—each of which has contrasting standards of living. In the Northern District the standard is definitely better than average. Earnings per employee in all industries run about 10 percent above those for the country as a whole. Relatively high incomes are especially typical of dominant manufacturing industries. Although the average income per farm usually is slightly below that of the entire nation, it is comparatively free from violent fluctuations. General prosperity is reflected in the large number of automobiles, telephones, and radios, as well as in high per capita retail sales, high rents, and high values of homes.

Distinctly lower standards of living prevail in the Southern District. The average income for both industrial and agricultural workers is perhaps 20 percent less than that for the nation as a whole. However, it should be pointed out that the poorest hill areas have so few people that they have only a small influence on general living conditions in the entire Basin.

III. Flood Control

Importance: The Ohio River is the principal flood-producing tributary of the Mississippi. Records show no major floods in the Mississippi, when the peak discharge of the Ohio has been less than 1,000,000 to 1,250,000 cu. ft. per second. During such floods, the Ohio not only contributes very largely to the flood damage along the lower Mississippi, but local flood damage along the Ohio and its tributaries is a matter of common knowledge. Flood abatement on the Ohio system, therefore, is of unusual importance from the point of view of general, as well as local, considerations.

Existing Projects: The Ohio Valley already has in operation a large number of local flood-control projects. Table 3 lists 34 of such projects, the total cost approximately $45,000,000, all of which was furnished by local beneficiaries, except about $1,500,000 as noted. None of these have any regulating effect on the flood flows of the Ohio.

TABLE 3.—*Ohio Basin—Existing flood control projects*

Location of project (1)	River system (2)	Type of protection (3)	Degree of protection (4)	Approximate cost (5)	Remarks (6)
Mounds—Mound City, Ill	Ohio	Levee	Complete	$320,000	1 continuous system.
Shawneetown, Ill	do	Flood wall and levee	do	529,000	U.S. and State contributed about 50 percent of cost.
Portsmouth, Ohio	do	do	Partial	745,000	
Jeffersonville, Ind. and Lawrenceburg, Ind.	do	Levees	do	145,000	Jeffersonville levee built by U S., cost $50,000.
Vincennes, Ind	Wabash	Flood wall and levee	Complete	300,000	
Peru, Ind	do	do	Partial	413,000	
Indianapolis, Ind	West Fork of White.	Channel improvements.	do	5,652,000	U.S. participation about $865,000 (C.W.A.).
Brevoort Levee system	Wabash	Levee	do	549,000	U.S. participation about $46,000 (C.W.A.).
Russell and Allison Drainage and Levee District.	do	do	do	569,000	
Oaktown Levee District	do	do	do	170,000	U.S. participation about $57,000 (C.W.A.).
Gill Township Levee District	do	do	do	128,000	
Island Levee Association	do	do	do	136,000	U.S. participation about $5,500 (C.W.A.).
McGionis Levee District	West Fork of White.	do	do	220,000	U.S. participation about $7,000 (C.W.A.).
15 additional projects on Wabash River and tributaries.	Wabash	do	do	780,000	U.S. participation about $170,000 (C.W.A.).
Lunken Airport, Cincinnati, Ohio	Little Miami	do	do	158,000	
Miami System, Ohio	Miami	Retarding basins and channel improvements.	Complete	30,000,000	
Kenton, Ohio	Scioto	Drainage channel	do	666,200	
Columbus, Ohio	do	Channel improvement.	do	3,500,000	
Zanesville, Ohio	Muskingum	Flood wall and levee	Partial	75,000	

Two projects [1] in the Ohio Basin have been authorized by the Public Works Administration and are now under way. One of them, the Tygart reservoir, because of the large Federal interest, is being financed by the Federal Government. The other, the Muskingum proj-

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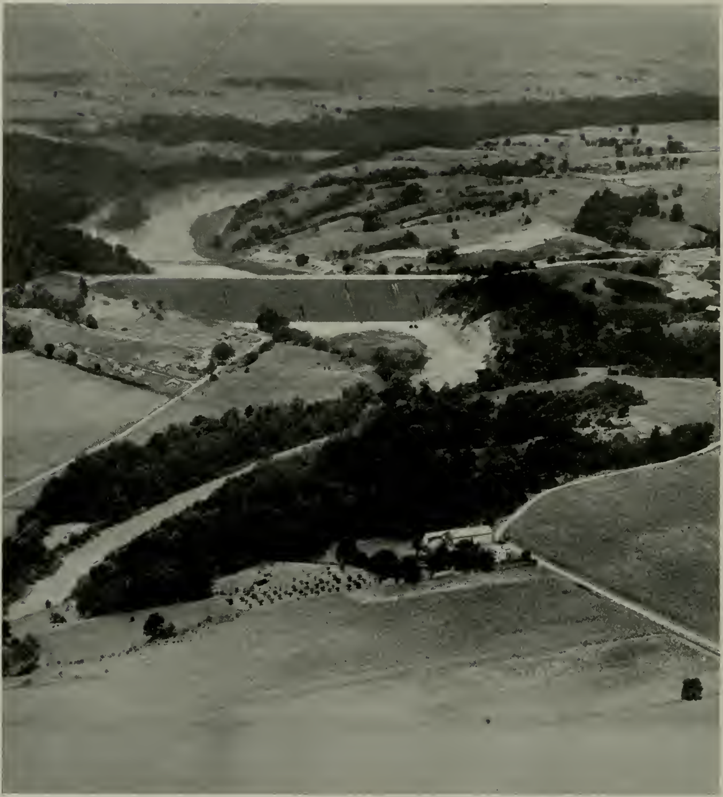
[1] This does not include the program of the Tennessee Valley Authority, which is being developed under a special enabling act and is essentially outside the scope of this report.



Typical flood-control dam, 125 feet high. The river is at normal. When flood comes the flow through the dam is limited by outlets at lower right; excess flood flow is held back in the natural basin above the dam. When the storm is over the basin is immediately emptied again, ready for the next flood. Thus the river valley downstream from the dam is protected against flood damage at all times.

ect (14 reservoirs supplemented by channel improvements) is being financed jointly by the Federal Government and the Muskingum Conservancy District in a proportion based on allocation of benefits. The Muskingum project will have a measurable effect in reducing flood crests on the Ohio. The estimated cost of these two projects approximates $46,600,000 (present authorizations).

Possibility of Reservoirs on Main Rivers: When considering the most effective plan for control of Ohio floods, so as to have the most beneficial effect on the floods of the Mississippi, a control reservoir on the main stem of the Ohio is the first thought that suggests itself. But analysis immediately reveals the inherent difficulties. Water stages at different points along the river, low to high water, range from about 40 to 70 feet. In other words, the river valley is, itself, in times of flood, a vast retarding basin or reservoir with an effective depth of 40 to 70 feet. A control dam, then, would have little merit until after its height exceeded that necessary to bring it above the low water stage as much as 40 to 70 feet, depending on its location along the river. Then, to be effective in control of big floods, it would need a capacity large enough to hold back a large part of a flow as great as 1,000,000 cu. ft. per second for a period of, perhaps, 10 to 30 days. This would require a capacity of 15,000,000 to 20,000,000 acre-feet, a volume of water that would cover an area of 1,560 square miles to a depth of 15 to 20 feet. Because of the development of communities along the Ohio it is probable that any such project would cause backwater flood damage that would more than offset any anticipated benefit downstream. The one or two possible sites, immediately suggest prohibitive cost figures. While no flood-control study of the Ohio, in relation to the Mississippi, would be complete without an investigation of the foregoing possibility, all preliminary considerations make it look extremely unpromising. In any case it may be said with some assurance that tributary control is the only possibility that offers hope for effective flood control generally in the Ohio Basin.

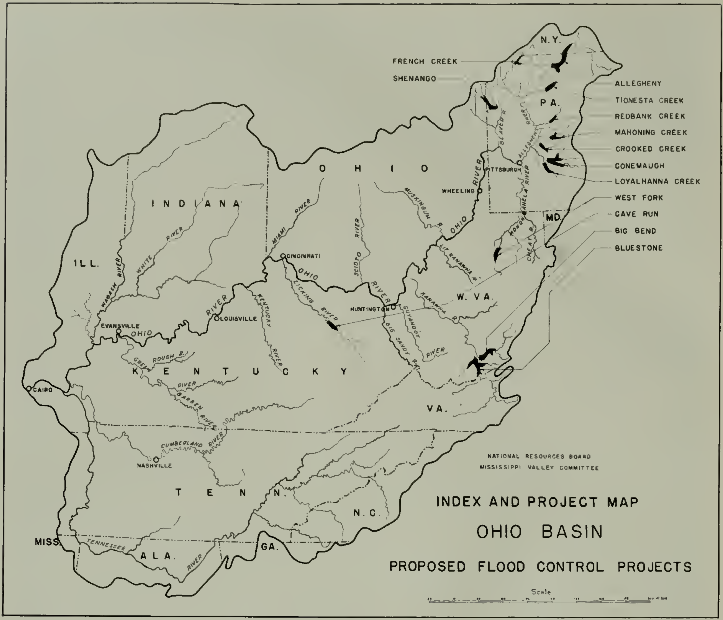
Tributary Control: It is by tributary control, combined perhaps with local levee systems, that local communities may expect to obtain a solution of some of their local flood problems. Flood storage reservoirs on the tributaries may well have a secondary effect of reducing flood crests on the Ohio (the Muskingum project has such effect) and it is conceivable that the combined effect of such projects might have a measurable effect on the Mississippi at and below its confluence with the Ohio.

Proposed Projects: A large number of such possibilities have been investigated and are discussed in the "308 Reports" of the Corps of Engineers. Table 4 gives pertinent data concerning 13 reservoirs which appear to deserve recommendation for inclusion in a coordinated flood-control plan for the Ohio Basin.

TABLE 4.—*Ohio Basin—Proposed flood control reservoir data*

				Estimate of cost						Estimated annual tangible benefits			
River system	Reservoir	Drainage area (square miles)	Capacity (acre-feet)	Land and buildings including rights-of-way for rail and highway relocation	Relocation of railroads and highways excluding cost of rights-of-way	Construction cost	Total estimated cost	Estimated annual cost maintenance and operation	Total annual cost, finance cost at 4 percent plus maintenance and operation	Federal	Along main Ohio River	Non-Federal above Wheeling, W.Va., and on tributaries	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Monongahela, Pa.	West Fork....	366	62, 500	733, 000	450, 000	626, 000	1, 809, 000	6, 500	79, 000	18, 000	29, 000	90, 000	137, 000
Allegheny, Pa.	Allegheny ...	2, 190	930, 000	3, 325, 000	7, 921, 000	6, 479, 000	17, 725, 000	28, 000	737, 000	76, 000	204, 000	613, 000	893, 000
Do....	Conemaugh..	1, 427	283, 000	1, 624, 000	9, 464, 000	3, 009, 000	14, 097, 000	16, 000	580, 000	34, 000	239, 000	364, 000	637, 000
Do.	French Creek....	541	140, 000	1, 331, 000	2, 142, 000	394, 000	3, 867, 000	6, 000	160, 500	13, 000	65, 000	149, 000	227, 000
Do.......	Tionesta Creek..	483	133, 000	706, 000	538, 000	2, 244, 000	3, 488, 000	9, 500	149, 000	12, 000	52, 000	115, 000	179, 000
Do...	Red Bank Creek..	460	143, 000	1, 912, 000	1, 851, 000	2, 206, 000	5, 969, 000	9, 500	248, 500	15, 000	88, 000	158, 000	261, 000
Do....	Mahoning Creek.	327	79, 000	193, 000	648, 000	2, 481, 000	3, 322, 000	10, 000	143, 000	9, 000	58, 000	99, 000	166, 000
Do......	Crooked Creek .	278	95, 000	232, 000	278, 000	1, 788, 000	2, 298, 000	8, 500	100, 000	12, 000	67, 000	105, 000	184, 000
Do.........	Loyalhanna Creek.	267	79, 000	486, 000	735, 000	1, 419, 000	2, 640, 000	8, 000	113, 500	8, 000	48, 000	80, 000	136, 000
Kanawha, W. Va.	Bluestone[1]........	4, 560	581, 400	2, 110, 000	630, 000	4, 800, 000	7, 540, 000	35, 000	337, 000	------	240, 000	400, 000	640, 000
Do.......	Big Bend........	1, 628	126, 500	897, 175	1, 298, 200	1, 319, 625	3, 515, 000	18, 000	158, 600	------	58, 000	100, 000	158, 000
Licking, Ky.....	Cave Run.......	731	112, 000	457, 000	20, 000	1, 337, 000	1, 814, 000	13, 400	86, 000	------	11, 800	148, 400	160, 200
Beaver, Pa....	Shenango River...	587	73, 900	587, 000	997, 000	449, 000	2, 033, 000	6, 000	87, 000	1, 000	8, 000	76, 000	85, 000
Total.	....	13, 845	2, 838, 300	14, 593, 175	26, 972, 200	28, 551, 625	70, 117, 000	174, 400	2, 979, 100	198, 000	1, 167, 800	2, 497, 400	3, 863, 200

[1] Bluestone Reservoir now being studied for possible power development in combination with flood control.



Index and Project Map for the Ohio Basin.

Effects on Ohio and Mississippi: In addition to the local benefits that would come out of execution of these proposed projects, expressed in annual value by the total of Column 13, there would result also, including the effect of the Muskingum and Tygart projects already approved, a measurable reduction in height of major flood crests in the Ohio River, estimated as five to six feet at Pittsburg, four to six feet at Cincinnati, two to four feet at Louisville, and one-half to one foot (in the Mississippi) at Cairo.

The latter corresponds to a reduction in crest flow of about 50,000 cu. ft. per sec.

Analysis of Costs and Benefits: The total estimated cost of these 13 reservoirs is about $70,100,000. The total annual cost (4 percent on the investment plus annual operation and maintenance cost) is estimated at $3,000,000. Estimated annual tangible benefits total about $3,900,000; the ratio of benefits to cost is about 1.3 to 1 without considering the many intangible benefits. The latter, because of their very nature, are difficult to evaluate. The value, for example, of a certain measure of flood-peak control on the Ohio goes beyond the direct benefit to navigation and to the communities along the banks of the river, but that additional value, while easy to recognize is hard to express in dollars. Similarly, any reduction of flood flows in the Mississippi has a recognizable worth, difficult to evaluate, A special study of the whole subject of methods of estimating flood-control benefits, tangible and intangible, is being made.

For the purposes of this report somewhat arbitrary estimates must be used, especially for intangibles.

Undoubtedly there is a Federal interest, beyond the tangible values expressed in Column 11, Table 4, in reduction of flood peaks on the Ohio and the Mississippi. Until the special study suggests a better plan, it is believed that for such intangible values, the Federal benefits might be increased by an amount equal to the amounts of tangible benefits expressed in Column. 11.

It is true that, similarly, there is a community interest along the Ohio, beyond the amounts shown in Column 12. Reduction of flood crests makes possible local protection works that otherwise might be impracticable or exceedingly expensive. But, in order to take advantage of that situation, local interests must themselves provide additional funds for such protection works. It seems reasonable, therefore, to increase the Federal benefits, as suggested, without making the approval of a project conditional upon a corresponding increase in local benefits.

Table 5 shows a suggested distribution of costs, for each of the 13 reservoirs, based on the foregoing suggestions, but adhering to the policy that the local (non-federal) participation shall be at least equal to the cost of Land, Buildings, and Rights-of-Way.

TABLE 5.—*Ohio Basin—Proposed flood-control reservoirs—Tentative cost distribution*

Reservoir	Total estimated cost table 4, column 8	Suggested Federal participation				Suggested non-Federal participation		
		30 percent of columns 6 and 7, table 4	Tangible benefits column 11, table 4, capitalized at 4 percent	Add for intangible benefits [1]	Total	Total column 2 less column 6	Along main Ohio River	Above Wheeling, W.Va., and on tributaries
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
West Fork	$1,809,000	$323,000	$450,000	[2] $303,000	[2] $1,076,000	[2] $733,000	$178,000	$555,000
Allegheny	17,725,000	4,320,000	1,900,000	1,900,000	8,120,000	9,605,000	2,395,000	7,210,000
Conemaugh	14,097,000	3,742,000	850,000	850,000	5,442,000	8,655,000	3,432,000	6,223,000
French Creek	3,867,000	761,000	325,000	325,000	1,411,000	2,456,000	745,000	1,711,000
Tionesta Creek	3,488,000	835,000	300,000	300,000	1,435,000	2,053,000	640,000	1,413,000
Red Bank Creek	5,969,000	1,217,000	375,000	375,000	1,967,000	4,002,000	1,431,000	2,571,000
Mahoning Creek	3,322,000	939,000	225,000	225,000	1,389,000	1,933,000	714,000	1,219,000
Crooked Creek	2,298,000	620,000	300,000	300,000	1,220,000	1,078,000	420,000	658,000
Loyalhanna Creek	2,640,000	646,000	200,000	200,000	1,046,000	1,594,000	598,000	996,000
Bluestone Creek	7,540,000	1,629,000			1,629,000	5,911,000	2,217,000	3,694,000
Big Bend	3,515,000	785,000			785,000	2,730,000	1,002,000	1,728,000
Cave Run	1,814,000	407,000			407,000	1,407,000	104,000	1,303,000
Shenango River	2,033,000	434,000	25,000	25,000	484,000	1,549,000	147,000	1,402,000
Total	70,117,000				26,411,000	43,706,000		

[1] Tentatively assumed to equal tangible benefits (column 4) except for West Fork, as noted.

[2] Non-Federal participation to equal cost of land, buildings, and rights-of-way. Federal participation to equal the remainder of the cost.

According to this schedule, Federal interest in these projects is such that possible Federal participation might go to the sum of about $26,400,000, while necessary non-Federal participation is estimated at $43,700,000. The latter amount should be assessed against the states and the communities benefited, whether on the tributary or on the main stem of the Ohio, in proportion to the estimated benefit to be received, in a manner similar to that provided in the Conservancy Law of Ohio. This will require suitable state and Federal legislation, which should accompany or precede the adoption of any comprehensive flood control plan of this character.

Program: It is believed that the foregoing set-up fairly represents a constructive program for Ohio River flood control, the next step of which should be detailed surveys, dam-site investigations, and the development of detailed plans. Included in these detailed investigations should be a study, for each reservoir, of the practicability of providing power facilities (for future development in most cases) without sacrificing flood-control value. Such facilities might be installation of power outlets for future use, or provision for future raising of the height of the dam to provide power storage.

A similar study of the possibilities of low water control should also be made. A restudy of estimated costs and benefits should be made, in view of these detailed studies and in the light of the most dependable information that can be secured.

The figures used in this preliminary report should be understood to be suggestive and tentative, based on the most reliable information now available. All are subject to modification as a result of more detailed surveys and investigations as and when these more detailed studies may be justified.

Including the Muskingum and Tygart Projects already approved, this program involves the expenditure of some $117,000,000; of which the Federal participation would be about $61,000,000 and local participation about $56,000,000. Further studies should include other reservoir possibilities which do not show economic justification under present conditions but which may, in the future, take a proper place in a more extended comprehensive plan.

IV. Navigation

Importance: The large volume of waterborne traffic on certain parts of the Ohio River System is accounted for to a large extent by the fact that the River flows in the direction of main traffic movements. Furthermore, bulk commodities, especially adapted to water hauling, are present in large quantities; water supply is sufficient for navigation throughout the year, with few exceptions; the climate is favorable for almost continuous navigation. The Monongahela leads all inland rivers of the country in volume of traffic. The Ohio itself carries more river traffic than does the Mississippi. Practically all this traffic is handled by private carriers who pay no tolls. In other words, under present policy, the construction costs and the operation and maintenance costs of navigation projects are at Federal expense, and no part of either of these costs is directly returned to the Government. The Committee believes that this policy should be modified (see "A National Inland Waterway Policy").

Existing Projects: Table 6 lists the existing navigation projects in the Ohio Basin exclusive of those on the Tennessee River, which are being included in the development program of the Tennessee Valley Authority and therefore are outside the scope of this report. The costs here shown do not include costs of operating the boats, nor of handling the freight, but are Federal costs only, no part of which is being paid by the users of the waterway. In some of these cases, however, the savings to the users are sufficient to provide for repayment to the Government of interest charges and operation and maintenance costs, in case such policy (recommended by the Committee wherever feasible) is adopted.

TABLE 6.—*Navigation statistics for Ohio Basin rivers*

River	Length of project (miles) 1	Controlling depth (feet) 2	Total United States construction cost to June 30, 1933 3	Fixed charge (4 percent of column 3) 4	Average operating and maintenance cost 5	Total annual cost (columns 4 and 5) 6	Tonnage, 1929 7	Ton-miles, 1929 8
1. Monongahela	131	8 and 7	$15,600,000	$625,000	$794,000	$1,419,000	28,908,000	1,147,434,000
2. Allegheny (open-channel portion)	163	1½ to 1	[1] 200,000	8,000	3,000	11,000	248,000	124,000
3. Allegheny (slack-water portion)	61	9	[1] 14,400,000	576,000	197,000	773,000	3,536,000	40,073,000
4. Youghiogheny	1	9	62,000	2,480	3,000	5,480	318,000	241,000
5. Muskingum	91	6	307,000	12,300	94,000	106,300	610,000	6,532,000
6. Little Kanawha	48	4	494,000	19,700	30,000	49,700	281,000	668,000
7. Kanawha	91	6	8,300,000	332,000	229,000	561,000	1,532,000	61,538,000
8. Big Sandy	57	6	1,650,000	66,000	36,000	102,000	80,000	439,000
9. Kentucky	203	6	4,176,000	167,000	205,000	372,000	156,000	27,231,000
10. Green and Barren	228	5	882,000	35,300	109,000	144,300	554,000	37,005,000
11. Rough River	30	4	105,500	4,220	1,600	5,820	10,700	227,000
12. Tradewater	3	9	2,500	100	500	600	2,000	6,000
13. Cumberland (above Nashville)	329	4½	4,198,000	167,920	108,500	276,420	256,000	11,281,000
14. Cumberland (below Nashville)	189	4½	4,772,000	190,880	72,500	263,380	307,000	7,218,000
15. Ohio	981	9	141,500,000	5,560,000	2,450,000	8,110,000	21,955,000	1,512,585,000

River	Cost to United States per ton 9	Cost to United States per ton-mile 10	Length of navigation season 11	Remarks 12
1. Monongahela	$0.049	$0.001	365 days	
2. Allegheny (open-channel portion)	.044	.089	275 days	Tonnage mainly gravel from dredging. Present operation and maintenance charges only nominal.
3. Allegheny (slack-water portion)	.218	.019	361 days	
4. Youghiogheny	.017	.023	362 days	
5. Muskingum	.174	.016	330 days	Tonnage figures for 1932 used, as tonnage increased to that time.
6. Little Kanawha	.177	.074	Entire year	
7. Kanawha	.366	.009	do	
8. Big Sandy	1.275	.232	do	Main stream and 2 branches. Tonnage figures for 1932 used as tonnage increased to that time.
9. Kentucky	2.385	.014	do	
10. Green and Barren	.261	.004	do	2 branches.
11. Rough River	.544	.026	do	
12. Tradewater	.300	.10	do	$17,500 spent on previous projects but not chargeable to present project.
13. Cumberland (above Nashville)	1.080	.024	do	
14. Cumberland (below Nashville)	.857	.036	do	Tonnage for 1932 used as traffic is increasing.
15. Ohio	.370	.005	do	

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[1] Estimated.

To illustrate the type of cargo and movements of traffic, there were shipped on the main Ohio River in 1929, coal and coke, 9,800,000 tons; sand and gravel, 9,100,000 tons; iron and steel, 1,600,000 tons; petroleum, 400,000 tons; and other cargo, 1,955,000 tons. Most of the coal and coke comes from mines along the Monongahela, Allegheny, and Kanawha Rivers, and is shipped downstream to Pittsburgh and vicinity, or to Cincinnati and Louisville. Sand and gravel is dredged from the river bed and generally is taken to the nearest wharf. The movement of iron and steel chiefly represents shipments from Pittsburgh steel mills to their subsidiary plants just below that city, but some 200,000 tons annually go to Memphis and other Mississippi River ports. It is evident, therefore, that most of the tonnage on the Ohio moves over only small sections of its available waterway. Upstream tonnage movements are relatively small.

Rearranging the projects listed in Table 6 according to costs per ton-mile, they take the following order:

River	Cost to the United States per ton-mile
1. Monongahela	$0.001
2. Green and Barren	.004
3. Ohio	.005
4. Kanawha	.009
5. Kentucky	.014
6. Muskingum	.016
7. Allegheny (slack-water portion)	.019
8. Youghiogheny	.023
9. Cumberland (above Nashville)	.024
10. Rough	.026
11. Cumberland (below Nashville)	.036
12. Little Kanawha	.074
13. Allegheny (open-channel portion)	.089
14. Tradewater	.10
15. Big Sandy	.232

Above, at left, rural scene in northern district. The substantial home and large barn reflect the productivity of agricultural land in this plains region. Right, farms and forests in the southern district. Only narrow valley bottoms and some favorable slopes are cleared for cropping.

Tow barges on the upper Ohio River. Steam or Diesel tugs push two to six barges loaded with coal, sand, steel, and other goods.

It should be noted that all of these ton-mile costs are based on a year of heaviest traffic, giving the project the benefit of favorable conditions. Considering the first four in the foregoing list, a not excessive charge per ton-mile would return to the Government its cost of operation and maintenance, interest on the investment, and, over a long period of time, all or a large part of construction cost. It is estimated that improvements now under way on the Kanawha will increase traffic and reduce ton-mile costs to about $0.007. While these are only four of the fifteen projects listed, they represent 85 percent of the total cost.

As to the last four in the list, the ton-mile costs are so high that there is little hope of any substantial returns to the United States for its construction and operation expense, or any part thereof. Nor is there any reasonable prospect of future traffic that will justify more than minimum possible operation and maintenance costs, except possibly on the Allegheny, where the Chief of Engineers estimates that a nine-mile improvement will being additional traffic that will result in a ton-mile cost of about $0.0055. These four projects represent only 1.2 percent of the total cost of those listed.

Projects numbered 5 to 11 in the list are in the intermediate class and conditions may develop whereby some of them might justify a charge that would return to the Government its operation and maintenance costs and perhaps part of the interest on its investment. Proposed future expenditures on these projects should be studied carefully with that thought in mind. A detailed study of projects in this group would show in each case whether savings to shippers are sufficient to warrant a service or license charge, to return to the United States all or a part of its expense, or whether the project has outlived its usefulness and should be maintained, if at all, at a possible minimum cost. Information is already available to indicate that probably the Rough River is in the latter class.

Betterments and Extensions: On the Ohio River are now being built two new fixed dams which will eliminate six of the existing dams on the main stream and also three on the Kanawha River; three new modern structures will also replace seven dams on the latter stream. The Allegheny River is likewise being modernized in its lower section by construction of two new dams replacing three obsolete structures. The dams on the Cumberland River are being raised to provide a navigable depth comparable to that available on the Ohio. On the Green and Barren Rivers modern locks of adequate dimensions are being constructed at two existing dams. The estimated cost of this work is $26,000,000.

Table 7 shows pertinent data regarding other similar projects in the Basin whose status is such that they are under active consideration for inclusion in a proposed future program.

TABLE 7.—*Contemplated navigation projects, Ohio River Basin*

Project	Location	Length (miles)	Estimated additional cost to United States	Estimated additional traffic (tons)	Estimated additional traffic (ton-miles)	Estimated increased maintenance and operation	Status	
							Adopted by Congress	Recommended to Congress
Cumberland	Above Nashville (Dams 9 to 21).	158	$3,000,000	No recent estimate.	No recent estimate.	Decreased $20,000 annually.		Yes
Green and Barren Rivers[1]	Rumsey to Glenmore	105	471,000	Probably none.	None	None		
Nolin River, Ky	Mouth to Meredith Ferry	8	15,000	do	None	1,000		Yes.
Allegheny River	Rimerton to East Brady	9	2,642,000	550,000	36,600,000	96,000		Yes.
Youghiogheny River	Mouth to West Newton	18	3,670,400	No recent estimate.	No recent estimate.	None made	Yes, 1910–1930.	
Beaver and Mahoning Rivers.[2]	From Ohio River at Rochester, Pa., to Struthers, Ohio.	35	37,000,000	6,000,000	210,000,000	640,000		Yes.

[1] This covers reconstruction of existing Dams, Nos. 2, 3, and 4, Green River.

[2] Discussed under "New projects."

Insufficient data are available to justify the proposed extension of the Youghiogheny project, and an estimate of additional traffic is needed to justify the proposed improvement on the Cumberland.

The proposed betterments on the Green and Barren Rivers and the proposed improvement of the Nolin River, in the opinion of the Committee, should await a reconsideration of policy whereby cost to the Government would be repaid by shippers who receive the benefit.

The same comment applies to proposed work on the Allegheny.

New Projects: At Youngstown, Ohio, and vicinity there is strong local sentiment urging the Government to undertake the Beaver-

Mahoning project to provide a 12-foot channel, to assure a 9-foot navigable depth, from the Ohio River to Struthers, Ohio, a distance of 35 miles. The cost of construction is estimated at $47,000,000, of which 10 million is proposed to be carried by local interests; the estimated annual cost of operation and maintenance is $640,000. Assuming that $37,000,000 of the construction cost to be carried by the United States will be charged off annually at 4 percent ($1,480,000 per annum) and, adding the annual operation and maintenance cost ($640,000), the annual cost to the United States would be $2,120,000. Estimated annual traffic according to the best figures available is 6,000,000 tons or 192,000,000 ton-miles.[1] According to these estimates, the Federal costs would be 35 cents per ton or $0.011 per ton-mile. Proponents of the project claim savings of from 50 percent to 100 percent in excess of those figures. The principal direct beneficiaries would be about six or eight large steel mills and perhaps an equal number of other heavy manufacturing or utility interests.

Compared with other navigation projects in the Ohio Basin, the ton-mile cost ($0.011) for proposed U.S. investment in construction plus operation and maintenance costs, is higher than that on the Monongahela ($0.001), the Green & Barren ($0.004), the Ohio ($0.005), and the Kanawha ($0.009), although, as has been said, prospective users could probably afford to repay this cost if that were the general policy. Unless or until an arrangement can be made whereby beneficiaries under a liberal repayment schedule will return to the Government its cost of construction, operation, and maintenance, it is suggested that a new project of this class might better be held in abeyance pending reconsideration of a new navigation policy.

V. Water Power

Present Power Facilities: Intelligent discussion of water-power possibilities in the Ohio Basin depends on covering the broad field of power, and on recognizing those competitive sources of steam power plants. The present installed capacity in plants generating electricity for public use in the Ohio Basin, plus the Lake Erie drainage in Ohio, is 5,469,000 kw., of which only 808,000 kw., or 14.8 percent, is water power. In 1929, the year of maximum output, all these plants generated approximately 17,000,000,000 kw.-hrs.

Estimated Future Requirements: Some 16 percent of the total energy generated in the United States in 1933 was produced in the Ohio Basin. The largest consumers are the wholesale light and power group. Their percentage of the total consumption in the United States was 35.8 in 1929 and 48.9 in 1932. The corresponding figure in the Ohio Basin for 1932 was about 52 percent.

Between 1919 and 1929 the aggregate horsepower of prime movers in the Ohio Basin increased 2,902,000 hp., of which 2,529,000 hp. was in electric motors driven by purchased current. Using these figures, and extending the 1919–1929 trend line from January 1, 1935, assuming no increases of any moment between 1929 and 1935, an indicated need for about 6,000,000 kw. by 1955 is shown. This means 3,000,000 kw. of new load. However, it is not believed that future increase in the industrial load will even begin to keep pace with that of the past 20 years, partly because the majority of the larger industrials are now electrified.

Domestic service has shown a steady increase each year, 1932 being 22.6 percent over 1929. A conservative estimate indicates that by 1955 there may be expected in the Ohio Basin and adjacent markets an increase of 4,300,000 people which should mean 650,000 new domestic consumers. The average United States consumption in this classification has shown a steady growth even during the depression, increasing from 339 kw.-hrs. in 1920 to 463 kw.-hrs. in 1929 and to 611 kw.-hrs. in 1932. Increased sales of electric refrigerators, ranges, and water heaters, and possibilities apparently existing in air conditioning would seem to indicate average use of 1,200 kw.-hrs. per domestic customer within 20 years.

Small light and power in the United States showed a 44-percent increase in consumption from 1926 to 1930, and an increase of 22 percent in the number of customers. For the Ohio Basin an increase in this group from 1,900,000,000 kw.-hrs. to 4,900,000,000 kw.-hrs. by 1955 would seem conservative.

The following table presents some interesting data from 1932 census relative to rural areas:

State	Number farms	Farm-houses lighted by electricity	Farms purchasing electricity	Percent farms purchasing
United States	6,288,648	841,310	571,007	9.0
Ohio	219,296	56,740	37,695	17.2
Indiana	181,570	30,335	18,569	10.2
West Virginia	82,641	5,330	2,844	3.4
Kentucky	246,499	10,691	5,863	2.4
Tennessee	245,657	10,010	6,720	2.7
	975,663	113,106	71,691	----------

---

[1] A part of this tonnage, perhaps a large part, would also go to increase traffic on the Ohio.

State	Average kw.-hrs. per customer	Number automobiles	Number telephones	Number radios
United States	[1] 802	4, 134, 675	2, 139, 194	12, 048, 762
Ohio	666	201, 552	121, 214	85, 038
Indiana	613	154. 556	110, 333	64, 252
West Virginia	----------	36, 978	28, 117	8, 966
Kentucky	----------	86, 784	61, 631	16, 862
Tennessee	----------	89, 022	45, 205	12, 401
	----------	568, 892	366, 500	187, 519

[1] For farms east of the 100th meridian. Farms west not included on account of large irrigation pumping load.

With extension of distribution lines into rural areas and, considering the educational work of the Tennessee Valley Authority, 150,000 new rural customers can be expected in the Ohio Basin by 1955. For the reasons given under domestic service, it is believed proper to estimate an increase in farm service in this area to the same figure used for domestic, namely 1,200 kw.-hrs. per annum, which will apply to present users as well as to new customers.

Municipal street lighting and miscellaneous users also will show some increases.

The following summarizes the estimated increased demand for power in the Ohio Basin by 1955:

	Kilowatt-hours
Farm and rural service	247, 800, 000
Domestic service	2, 340, 000, 000
Small light and power	3, 000, 000, 000
Large light and power	10, 500, 000, 000
Municipal street lighting	300, 000, 000
Miscellaneous	150, 000, 000
	16, 537, 800, 000

Based on 16 percent loss from bus bar to customer, there would be required a total additional output of 20 billion kw.-hrs. With the same load factor and ratio of excess or spare capacity in generating plants as at present, something on the order of 5,800,000 additional kw.-hrs. of generating capacity will be required by 1955.

Water Power Available: The most comprehensive and detailed survey of available water power in the Ohio Basin is that recently made by the U.S. Army Engineers, referred to as the "308 Reports." While the 200 projects listed are impressive as to quantity and apparent low cost per unit of development, two highly significant factors must be remembered when considering them: (1) proposed plants on each stream are based on complete development of that stream, and storage considered for the upper plant is also used in lower plants. Therefore, unless storage of equal amount could be provided for a selected development, the amount of energy available would be lower. (2) In general a low load factor has been estimated, since many of the plants will be used to carry the peaks in systems with large steam capacities. As a result proposed installations are high, thus reducing the estimated cost per unit of installation.

It also should be pointed out that these developments would be practically in the best coal fields in the country, and that kw.-hr. costs would be carefully considered against steam-power costs. Large mine mouth steam plants costing $90 per kw. and capable of producing a kw.-hr. on the bus bar with 1¼ pounds or less of coal would show a cost with a reasonable load factor of less than four mills per kw.-hr. on the switchboard, and could probably be located more advantageously so far as market is concerned than could the hydro plants. Therefore, as a general rule, no hydro plant would be considered unless its cost were less than steam-power costs, although certain conditions such as cost of carrying peak load only, which would result in a low-load factor, or the particular market to be supplied, such as an electro-chemical plant which would absorb a large amount of secondary energy, would be exceptions to the general rule.

Possible Water Power Developments: Power development in the Ohio Basin will usually require regulation of the flow by storage.

Numerous problems must be considered in a proper determination of the type of generating plant to be installed. In the final analysis decision as to type of plant is based on an economic condition. Generally speaking, the type which can deliver a kw.-hr. in the market at lowest cost is the one selected.

Apparently but few, if any, of listed water-power projects in this area can meet the generating cost of modern steam-power plants (4-mills or less) else more than 15 percent of the present installed generating capacity would be in hydro plants. Complete development of the Kanawha River drainage would show about 1,350,000 kw. installed at an estimated cost of $130 per kw. The output is estimated at 4,900,000,000 kw.-hr. of which over 2,800,000,000 kw.-hrs. would be primary energy. About 600,000 kw. of the installation could generate prime energy at a cost of five mills or less per kw.-hr. The Cheat River completely developed would have over 700,000 kw. installed at an estimated cost of $126 per kw.

with an output of 1,504,000,000 kw.-hrs. of primary energy. About 350,000 kw. of the installation would produce 677,000,000 kw.-hrs. of prime energy at a cost of five mills or under per kw.-hr. These appear to be the most promising of the undeveloped water-power projects, and might well be considered in a long time plan of development. The estimated cost of this work for the Kanawha would be $175,000,000 and for the Cheat, $88,000,000.

While it seems that there will be a demand for a large amount of additional generating capacity in the next 20 years, and that there is an abundance of water power available, to what extent the demand will be supplied by hydro plants will depend largely upon the probable cost of energy from such plants as compared with the cost from competitive sources of supply. Of the 13 reservoirs proposed for flood control the nine on the Allegheny and Monongahela Rivers have been carefully studied by the Army Engineers as to their possibilities for combined use with water-power development, but so far such use has been found undesirable. The Bluestone Reservoir on the Kanawha is now being so investigated. The remaining three will require further field investigation to determine possibilities of enlargement and combination use.

The program of the Tennessee Valley Authority will result in additional power being made available to serve a large section of the Ohio Basin. Also it will demonstrate some of the possibilities of increasing power use both by development of new and broader markets, new and wider uses in the same market, and by showing what may be expected as to increased consumption, due to lower charges for current, and lower prices of power-consuming equipment, particularly of the household and farm-use type. In view of this, and the preceding sections of this report, no recommendations are made for early consideration of specific water-power projects in the Ohio Basin, in addition to the Tennessee Valley developments that are being, and may be, undertaken.

VI. Soil Erosion Control

The Problem: While it is definitely known that soil erosion in the Ohio Basin is widespread and in some sections very serious, satisfactory information is not available as to the location, extent of the areas affected, and amount of damage already done. The general map indicates in broad outline the region in which the soils are suffering most severely. The process of soil depletion by sheet erosion, and in certain regions by severe gullying, is so great that vigorous action is necessary to introduce effective measure of control.

Public Activities: Establishment of public forests and advance in forest-fire protection is aiding in erosion control in mountain areas. Extension teaching and state cooperation are proving effective in aiding farmers to adopt better methods of land use. There are 50 to 60 C.C.C. camps in the Basin where the main work is in gully control and other activities related to soil erosion. The United States Soil Erosion Service has established four demonstration areas in the Basin, one each in Ohio, West Virginia, North Carolina, and Alabama. The Bureau of Chemistry and Soils has an Erosion station for research and experiment in Ohio. The Tennessee Valley Authority is also conducting extensive erosion control work.

Future Program: Beyond operation of demonstration tracts, and development of educational programs, the outline of detailed activities for the Ohio Basin must necessarily await the results of the soil erosion surveys and investigations now in progress. It is not too late to save the soils of the Ohio Basin if an effective large-scale policy of erosion control is initiated promptly by public agencies.

VII. Sewage and Waste Disposal

Importance: The Ohio Basin enjoys a greater average annual precipitation than any other major tributary basin of the Mississippi. Its population density, however, particularly the urban element, is high. In addition it is a great industrial region. These factors make the total demand on water resources so great that sewage and waste disposal and water supply constitute important features in any plan for wise use of such resources in the Ohio Valley.

Present Condition: The four important types of pollution existing in this region are (1) industrial wastes, (2) waste water from coal mines, (3) waste oil from oil fields and refineries, and (4) sewage from cities. All four types of pollution can be abated by proper methods of disposal. The Ohio River Interstate Stream Conservation Agreement, the objective of which is protection of public water supplies against harmful pollution, has initiated progressive work in control of industrial and coal mine wastes.

Coal Mine Wastes: Through State cooperation and the aid of Civil Works Administration funds, sealing of abandoned coal mines has been made possible. However, little has been done in this field since the withdrawal of C.W.A. funds.

Industrial Wastes: Control of industrial wastes is an important factor in the Ohio Basin. In most cases this is done at the plant and, in the case of taste and odor producing substances in tar-acid phenol waste from coke ovens, notice is given downstream cities in event of breakdown at the control works.

Control of pollution from oil fields has been affected to some extent by the Oil Pollution Act of Congress of 1924.

Sewage from Cities: The U.S. Health Service in 1915 estimated that 82 percent of the urban population of the Ohio drainage area contributed sewage to the drainage system. Recent surveys elsewhere substantiate this estimate as reasonably accurate for present conditions. Applying this figure to the total urban population of the Ohio River drainage area above Cincinnati in 1930, we find that the sewered population in 1930 would be approximately 3,240,000 as compared to 2,370,000 in 1915, an increase of nearly 37 percent in sewered population in the past 15 years.

In spite of this increase, the trend of stream pollution has been toward a betterment of conditions in recent years due chiefly to sewage treatment and waste control. Two sewage-treatment plants and seven sewage-disposal plants in this region are now under construction with the aid of Public Works Administration funds, and 38 additional sewer projects in this area have been approved for Public Works Administration loans.

Problem Areas: The United States Public Health Service is now making a study of this drainage basin, which will give the industrial equivalent from which the pollution load of each stream can be determined. Indications are that this data will be available in time for later studies, making it possible to consider some of the problem areas.

VIII. Water Supply

Present Conditions: The Census of Municipal Water Purification Plants in the U.S. for 1930 lists 386 water-purification systems in the Ohio River Basin. Of these 302 depend on surface waters for their supply and serve 5,342,000 people or 31 percent of the population of the Basin. Compared to this 84 plants obtain their supply from ground waters and serve 572,000 people or 3 percent of the population. To the plants listed should be added 59 more, which will be built by P.W.A. cooperation. Improvements of over 200 existing waterworks in the Ohio Basin are also in process through the P.W.A. program.

There are only 25 cities and towns of over 1,000 population in the Ohio Basin reporting no waterworks. Of these two are in Illinois, four in Indiana, five in Kentucky, nine in Ohio, five in Pennsylvania, and nine of the 14 States partly in the Ohio Basin have no cities (in the Basin) of over 1,000 reporting no waterworks.

Problem Areas: Water-supply-problem areas are easily located by a serious drought such as that of 1930 or that of the present summer, 1934. In Kentucky a number of towns suffered water shortage which forced them to secure water from emergency sources. Other towns suffered from decrease in quality of water due to low stages of rivers, and a rather wide outbreak of acute intestinal disturbances occurred in January and February 1931, due to decreased and polluted water supplies. During 1930, 13 cities and villages in Ohio were forced to take extreme measures to secure a water supply. Other cities in the Basin experienced a corresponding water shortage, the degree of which depended on the type of existing water system, storage facilities, and water supply.

Planning for the Future: Quantity and quality are the two important factors concerning use and development of river sources of water supply. Quantity available for water supply is determined by flow of the stream under adverse conditions of drought and influence of the use of the stream for other purposes. The quality of the water is determined by the geologic formation of the catchment area and by the use of the stream for disposal and transportation of waste. Practically nothing can be done to increase the total quantity of water available in a stream, but considerable regulating effect can be made on the low stages of stream flow by storage control. The quality of water can be rather definitely controlled within reasonable limits.

Demand for quality water is constantly increasing. The quality of the sources is, in most cases, tending to decrease. In addition, the quantity of water for waste disposal and transportation is decreasing and the amount of sewered population and waste to be disposed is increasing. These factors, together with the danger of contamination in periodic water shortages, are imperative reasons for having a well-defined program of future development.

The place of the Government in this program seems to be to furnish basic data as to stream flow or other sources of supply, to promote educational work in protection of water supplies and control of pollution. The job of providing new or additional water supplies must necessarily remain the obligation of the communities interested.

IX. Recreation

Discussion: Recreation has become a public problem only in the last generation. In former days there were ample facilities for out-door recreation, accessible to all who had leisure. In recent years, however, open lots in cities have been progressively occupied by buildings; private owners have closed to the public their woods, their ponds, and their streams. At the same time the urge for recreation has greatly increased in every class of people. A national plan of recreation is being developed and should be encouraged along constructive lines.

Recreational Areas in the Ohio Basin: Some of the larger cities of the Ohio Basin are among the leaders in providing local recreation facilities for their citizens. In addition to the large number of city parks and playgrounds, there are five National Forests, with areas totaling 5,500,000 acres, and one National Park (Smoky Mt. Park) with an area of 300,000 acres. Pennsylvania has 100,000 acres in the Ohio Basin in State forests and parks. Ohio has seven State forests, and seven State parks, covering 60,000 acres or more. Indiana has 35,000 acres in five State forests and nine State parks. Illinois has one State forest and three State parks. Kentucky has nearly 20,000 acres in two State forests (including one owned by the State University) and seven State parks. Tennessee and North Carolina have furnished the Big Smoky National Park. West Virginia has 15,500 acres in two State forests. In addition most of the States in the Ohio Basin have game refuges on public or private lands.

Facilities for Recreation Projects: Exceptional natural facilities for out-door recreation abound in the Ohio Basin. The beautiful countryside and the many points of historic interest are attracting increasing numbers of people to this region. Although the Basin is lavishly endowed with beautiful streams, waterfalls, and impressive rivers, it is notably lacking in natural lakes and ponds. Construction of artificial lakes and pools in connection with navigation, flood control, and power projects will add greatly to the charm of this area. In a recreation project size, in itself, is not a too important factor. Many small projects, so located as to serve a large number of people, may be quite as effective as a smaller number of large areas.

An Example of Adaptation: Here is one example of a recreation project consisting of relatively small areas which has been developed in connection with the flood control works of the Miami Conservancy District. At four of the five dams, certain areas (totaling 1500 to 2000 acres) have been designated for public use as natural camping and picnic grounds. Approved spring waters have been protected and marked. While the flood control dams form retarding basins and, therefore, have no permanent water behind them, the large borrow pits at two of the dams form miniature lakes which are stocked with fish; and one of them, supplied by clean rising waters, is excellent for bathing. These areas are within easy reach of several hundred thousand people and are widely used. These recreational areas are maintained at a minimum of expense; only two extra patrolmen are required for the six months, May to October, inclusive, one at each of the two areas where the use is heaviest. At the other areas the regular caretakers at the dams are able to handle all of the work.

There are opportunities for many recreation projects in the Ohio Basin in connection with various water projects in existence and projected. They should be encouraged as part of any comprehensive plan for development of water resources and allied activities.

THE MISSOURI BASIN

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I. Economic and Social Characteristics

The seven and one-half million inhabitants of the Missouri Basin are distributed in three major zones of human occupation, each representing a distinctive group of adjustments to conditions of the natural environment.

A. *The Eastern Zone:* The eastern third of the basin is characterized by moderately dense settlement, a relatively stable and diversified agriculture, and an increasingly important urban life based in considerable part on the manufacture and distribution of commodities used or produced in the middle and western zones. It contains, indeed, most of the people and nearly all of the larger cities and manufacturing industries of the basin. The density of population, which everywhere exceeds 12 persons per square mile, and in some localities 60 persons, diminishes gradually to the west. During the last decade the cities have grown consistently, while the populations of most rural districts have declined slightly or remained stationery.

This is the "commercial front" of the basin. The cities along the lower reaches of the Missouri River are commercial intermediaries for the remainder of the drainage area. They mark in rough fashion the border of the northeastern manufacturing belt of the country. They stand as junction points between the closely spaced railroad pattern of the East and the widely separated transcontinental lines of the West. Their continued growth is an expression of a wave of urbanization and of manufacturing that has been moving westward at a slow rate.

Except in the Missouri portions of the rugged Ozark Plateau and the contiguous Lowland, at least 40 percent of the land of the eastern zone is in crops, the farm units are of moderate size, and the prevailing farm practice is diversified. The corn belt intersects the zone, and accounts for the westward bulge of comparatively high population density in Nebraska and Kansas. Winter-wheat farming merges with corn culture to the south, and spring-wheat farming is dominant to the north. In general, the line of 20 inches of average annual precipitation bounds the zone to the west, and constitutes the approximate limit of consistently successful crop production without irrigation. In most parts of the eastern lowlands and the adjoining border of the Great Plains, agriculture is well established and normally yields a fairly comfortable living, but on the Ozark Plateau, and in portions of southern Iowa and northern Missouri, infertile and erosive soils have restricted prosperous farming and have induced the abandonment of numerous farms in recent years.

Although the agricultural assets of most of the Ozarks are relatively meager, the more effective utilization of their forests and forest lands for water conservation, control of soil erosion, lumber, and recreation is a matter of urgent importance.

B. *The Western Zone:* In western Montana and on the Colorado Piedmont there are a few concentrations of population which, with their complements of cities and radial alignments of transportation facilities, are founded chiefly on mineral industries or irrigation agriculture.

Most of these groupings, on or adjacent to the slopes of the Rocky Mountains, have gained notably in population in recent years, although a few mining towns have declined as mineral deposits have been depleted or exhausted. Separating these "islands" of growing population there are sparsely settled mountainous areas, mostly forested, or semiarid plains, in considerable part publicly owned, which are not suited to cultivation.

The irrigated oases in the otherwise pastural piedmont or the intermontane basins return moderate to heavy yields of sugar beets, other vegetables, and forage crops. A dependable and adequate supply of water is required in these oases not alone to insure consistent harvests of cash crops, but also to provide supplemental feed for livestock grazed on the pastures of the surrounding plains and the mountains. The beet factory, the canning plant, and the loading pen are distinctive features of the scattered towns.

Violent fluctuations in the urban populations of various districts in the western zone have accompanied the exploitation of metal resources. However, the utilization of the vast coal deposits and the petroleum deposits within the zone has involved, and in the case of the former probably will continue to involve, less uncertainty of occupation. The coal industry has been developed only slightly, while the petroleum industry appears to be approaching a peak of production.

C. *The Middle Zone:* Between the eastern and western zones of the basin lies a vast middle zone that is characterized by a relatively sparse and unstable population. The density of population exceeds 12 persons per square mile in only a few places. The moderate-sized towns are strung out irregularly along the transcontinental railroads. The record of the settlement of the zone, which has followed these railroads lines in the main, has been one of violent changes and of great movements and countermovements of people.

Efforts to occupy and exploit the middle zone have depended chiefly on agriculture. With the development of dry farming, of highway and railroad facilities, and of power machinery, farmers extended the culture of wheat over the dark prairie soils of Montana, the Dakotas, Nebraska, and Kansas, where previously grazing had been the dominant economic activity. Large farm units devoted to a single cash crop have been the rule. Some settlers have turned to irrigation farming, especially in times of water shortage. Notwithstanding technical improvements in both dry-land and irrigation farming, however, the middle zone remains a land of great economic hazards, an unconquered frontier of settlement. The normally meager rainfall and the alternating periods of wet and dry years have promoted many faulty and insecure adjustments to the plains environment. Time and time again "dry farmers" have found themselves stranded in great numbers during drought periods. A case in point was the migration of wheat farmers into eastern Montana in 1914–1916, an advance followed subsequently by a disordered retreat as a consequence of inadequate rainfall. On some of the irrigation enterprises the works for the control and distribution of water have seemed barely justified in years of moderate rainfall, and in many instances they have been abandoned or permitted to fall into disrepair in years of relatively abundant rainfall. No certain formula for wide-spread agricultural success on the semiarid plains has been developed, and no easy solution is within sight. The zone seems likely to continue as an area of experimentation in land utilization, of painful trial and error. Further shifts and realignments in its occupation may be expected in the near future.

Manufacturing is of slight significance, and by and large there is little foundation for its development. Mining is of importance chiefly on the slopes of the Black Hills Uplift.

Whereas relative stability is evident in the eastern and western zones, chronic instability is the outstanding characteristic of the middle zone. In general, therefore, Federal participation in projects for the use and control of water in the middle zone is accompanied by greater risk than in the other zones, but it is no less justified, provided the mistakes of the past are not repeated, and it is even more urgent.

II. Problems of Water Use and Control

In almost any locality in almost any part of the Missouri Basin the people face one or more urgent problems of water. For example, there are areas with grave flood risks, with insufficient water for irrigated farms, with failing water supplies for domestic and municipal purposes, or with soils seriously depleted by water erosion. To minimize the menace of waters and to promote their greatest usefulness are objectives the realization of which is essential to the development and maintenance of the highest standard of living possible in the great drainage area. The following pages discuss briefly the major problems that are involved in the realization of these objectives.

A. Flood Control

1. *The General Problem*: The average annual flood losses within the Missouri Basin during the last few decades have been estimated tentatively at about $2,800,000, a figure that might be doubled if the intangible losses could be evaluated. About 2,275,000 acres of farm land in the basin and some twenty-six municipalities, with a combined population of 730,000, are subject to floods. As indicated on the accompanying project map the flood hazard is localized in the headwater areas and in the Kansas River-Lower Missouri area.

Flood protection by means of reservoirs is considered as possibly feasible only in the case of the Kansas River. The Kansas State Planning Board reports that three reservoirs could be constructed in the upper Osage Basin to benefit a number of towns through flood-protection and augmented flow during low-water periods. No data are in hand, however, by means of which the technical or economic feasibility of this possibility can be evaluated. The Fort Peck Reservoir will have no appreciable effect on floods along the lower Missouri, and it cannot be operated effectively for flood prevention. Elsewhere the solution to the flood problem calls for levee projects at scattered communities, yielding benefits largely local in character.

The following table and the accompanying map indicate thirteen flood control projects in the Missouri Basin that are worthy of further consideration. Those listed in Class A are deemed economically feasible for immediate construction under terms discussed elsewhere in this report (see page 24). Estimates

MISSOURI BASIN

WATER-POWER PROJECTS

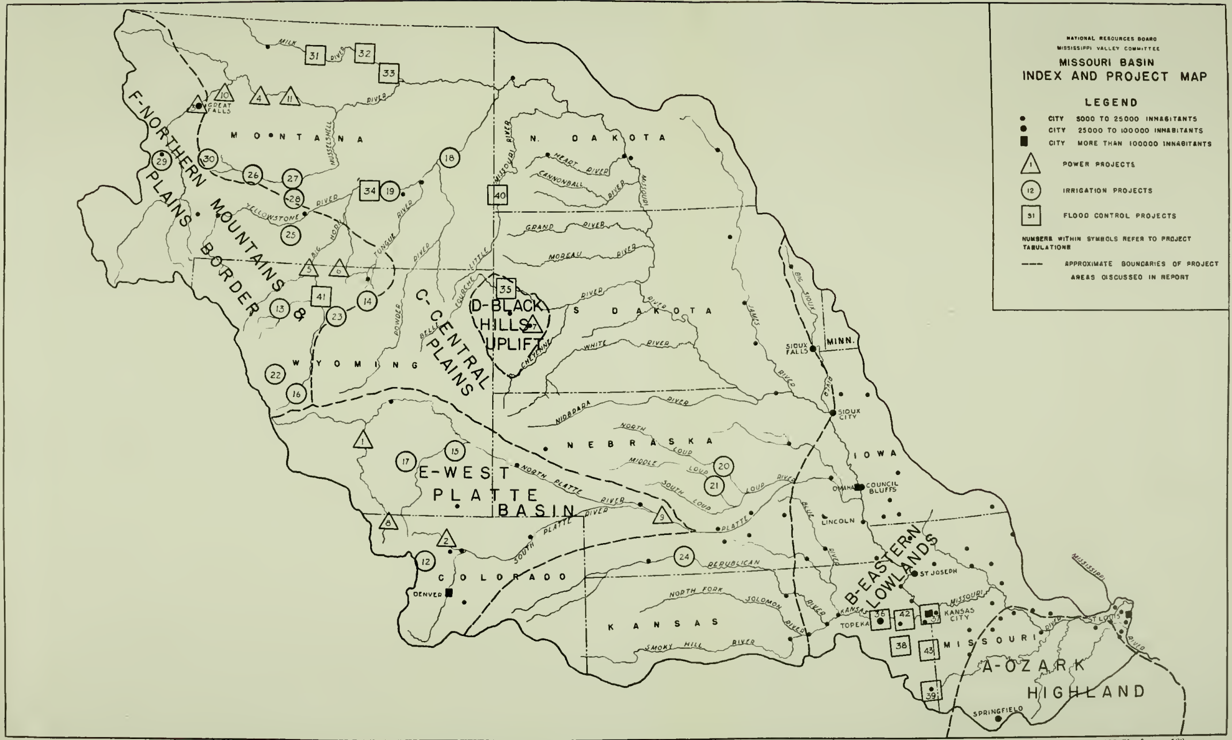
	CLASS A		CLASS B
Map reference No.	Project	Map reference No.	Project
1	Seminoe	7	Pactola
2	Elkhorn	8	N. Platte River
3	Portage	9	Sutherland-Plum Creek
4	Iliad	10	Fort Benton
5	Big Horn	11	Bearpaw
6	Little Horn		

IRRIGATION PROJECTS

	CLASS A		CLASS B
12	Northern Transmountain Diversion	20	North Loup Group
13	Greybull Valley	21	Middle Loup Group
14	Rock Creek	22	Freemont Canal
15	Wheatland	23	Paintrock
16	Lander Valley	24	Joliet
17	Medicine Bow	25	Harlowtown
18	Buffalo Rapids	27	Franklin
19	Cartersville	28	Fish Creek
		29	Silver
		30	Woods Gulch

FLOOD-CONTROL PROJECTS

	CLASS A		CLASS B
31	Harlem, Mont.	41	Greybull, Wyoming
32	Saco, Mont.	42	Lawrence, Kan.
33	Glasgow, Mont.	43	Osawatomie, Kan.
34	Forsyth, Mont.		
35	Belle Fourche, S.Dak.		
36	Topeka, Kan.		
37	Kansas Cities		
38	Ottawa, Kan.		
39	Fort Scott, Kan.		
40	Marmarth, N.Dak.		


NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE
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of their feasibility are based entirely on the tangible benefits involved. The Class B projects require further study to determine whether or not they are feasible, though present indications are that their construction will be economically justified if intangible as well as tangible benefits are considered.

Flood-control projects

Map reference number	Project	Population	Average annual flood loss	Construction cost plus capitalized O. & M.
	CLASS A			
31	Harlem, Mont	708	$1,410	$25,000
32	Saco, Mont	506	3,160	50,000
33	Glasgow, Mont	2,216	3,180	56,000
34	Forsyth, Mont	1,838	7,860	127,000
35	Belle Fourche, S.Dak	2,032	4,800	52,000
36	Topeka, Kans	64,120	132,600	2,380,000
37	Kansas Cities	521,603	1,371,825	20,240,000
38	Ottawa, Kans	9,563	42,250	882,000
39	Fort Scott, Kans	10,763	12,200	150,000
40	Marmarth, N.Dak	721	4,350	80,000
	CLASS B			
41	Greybull, Wyo	1,806	9,620	238,300
42	Lawrence, Kans	13,726	16,960	417,000
43	Osawatomie, Kans	4,440	16,850	406,000

The Kansas Cities, Topeka, and Lawrence projects are discussed later as a group problem. The remaining items in the "Class A" list represent eight individual projects to protect as many communities, with an aggregate population of 28,447, at a cost of $1,442,000.

2. *The Problem of the Kansas Cities:* Greater Kansas City has the most serious flood problem in the Missouri Basin, if not in the United States; provision for its adequate protection constitutes the most urgent water project of any kind in the Missouri Basin. Tangible damages of more than $20,000,000 were caused by the flood of 1903, and the figure for such damages might be doubled today by a flood of similar magnitude. Intangible damages that cannot be computed would result from the flooding of bottom land industries which in 1930 did a daily business of more than $1,000,000, and of the crowded railroad yards in one of the Nation's more important transportation centers. The maximum flood against which the present protection works along the Kaw River suffice is one with a probable periodicity of about once in twenty years.

The solution of the Kansas City flood problem is technically difficult because it involves two rivers, the Kaw and the Missouri, and otherwise difficult because it involves two states, the conflicting laws of which now prevent active cooperation. However, these very difficulties add much to the significance of a problem, the successful solution of which, through the *cooperative* efforts of local, state, and Federal interests, may well set a highly desirable precedent.

A gratifying amount of local cooperation already has been given the Mississippi Valley Committee in its preliminary studies of the Kansas City situation. The chief engineers of all the railroads affected by the project have formed a committee which has furnished a wealth of valuable technical data. A flood-control committee appointed jointly by the two chambers of commerce, Kansas City, Kansas, and Kansas City, Missouri, has undertaken a study of the new legislation that will be necessary to enable the two states to work together, and has begun a detailed social and economic survey of the bottomlands.

Technically, the Kaw River problem should be solved first, since the nature of its solution will affect materially the design of levees along the Missouri River.

The crowded industrial development of the Kaw River bottoms, suggested by the accompanying airplane view throws doubt on the feasibility of their complete protection by levees. The Kiro dam, suggested as an alternative, is impracticable because of the excessive cost of flowage rights and because of the fact that its construction would endanger a high culture on land of great fertility. But indications are that the potential Milford and Tuttle Creek reservoirs on the Republican and Blue rivers, respectively, would in 1903 have given adequate protection along the Kaw River from Manhattan to Kansas City, including Topeka, Lawrence, and a number of smaller communities, if combined with some local levee work, the extent of which has not yet been determined.

While technically less effective than the proposed Kiro Reservoir, the Milford and Tuttle Creek reservoirs seem to have compensating advantages as follows: (1) the sites contain no main-line railroad trackage; (2) the narrowness of the reservoirs would permit farming on the bottoms on a possible average of nine years out of ten; and (3) fewer towns and fewer homes would have to be moved than in the case of the Kiro Reservoir. The two reservoirs probably would not lend themselves, however, to multiple purpose operation, their utilization for flood prevention apparently precluding any incidental benefits such as the generation of power or utilization for recreation.[1]

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[1] It is possible that, in the event of construction, earth for the dams may be taken from upstream borrow pits, which in turn could be used in creating lakes for recreational use.

3. *Reservoirs to Ameliorate Floods in the Lower Mississippi:* A system of six reservoirs in the lower Missouri Basin, involving a total cost of about $86,000,000, would have resulted in a total reduction of 25 inches in the Cairo flood stage of 1927. These proposed reservoirs seem to constitute the only combination in the Missouri Basin that possibly may prove feasible as a means of lowering floods on the lower Mississippi. They are the Osceola, Pomme de Terre, and South Grand reservoirs in the Osage Basin, the Chillicothe Reservoir in the Grand Basin, and the Richland and Arlington reservoirs in the Gasconade Basin. Of the group, only the Osceola Reservoir, the cost of which is estimated at about $31,000,000 would alone have had an appreciable effect on the 1927 Mississippi River flood. It would have brought about a stage reduction of approximately one foot at Cairo, at a construction cost of something more than $2,500,000 per inch of reduction.

4. *Recommendations and Conclusions:* (1) It is recommended that the following projects be given favorable consideration in accordance with the principles advocated for projects involving chiefly local benefits (page 28): Harlem, Montana; Saco, Montana; Glasgow, Montana; Forsyth, Montana; Belle Fourche, South Dakota; Ottawa, Kansas; Fort Scott, Kansas; and Marmarth, North Dakota.

(2) The intangibles inherent in the Kansas Cities situation indicate that adequate flood control there would bring about Federal as well as local benefits, associated with such matters as (a) the protection of interstate transportation; (b) the protection of that part of the nation's food supply dependent on Kansas City's great meat-packing industries; and (c) the protection of life and health in a crowded metropolitan area.

It is urgently recommended that an immediate technical and economic investigation be made (a) of the practicability of lowering flood peaks on the Kansas River through the Milford and Tuttle Creek reservoirs, and of combining such regulation with flood protection by means of levees at Kansas Cities and other municipalities on the Kansas River, and (b) of any alternative possibilities worthy of consideration. The Corps of Engineers estimates the cost of such an investigation as $25,000. The investigation should be carried on by the Federal Government and local interests, working cooperatively, and should have as one of its aims the determination of ways and means whereby a comprehensive interstate conservancy district may be formed, which later can participate in construction if that is undertaken. In this cooperative investigation, the Federal Government should be represented by members of the Corps of Engineers and of the Water Resources Section of the National Resources Board. In the event that the Federal Government agrees to bear part of the cost of the investigation, immediate steps should be taken to secure local cooperation, shared by the railroads and industries affected as well as by the various municipalities and drainage districts.

(3) No reservoirs in the Missouri Basin for the amelioration of Mississippi River floods should be considered, except as elements in a comprehensive and coordinated system of reservoirs involving other members of the Mississippi System as well as the Missouri drainage. The best combination of reservoirs to accomplish a highly desirable reduction of two feet or more in the flood crests at Cairo, might not include any reservoirs in the Missouri drainage area. Despite its greater length, the Missouri contributes far less water during most floods than some other rivers, notably the Ohio and Arkansas, to the master stream.

B. Use of Water for Irrigation

1. *Importance:* Irrigation, where successful, is of prime importance in the semiarid section of the basin. It makes a farmer who has an *adequate* and *dependable* water-right largely independent of the uncertain rainfall, and tends to increase the yield of his land. It helps to support the grazing industry by furnishing feed for stock. It furnishes towns and cities nearby with foodstuffs otherwise procurable only from more remote sources of supply at higher cost. It contributes to the commercial upbuilding of such communities. It aids flood control through regulation of stream flow.

Conservative, sound extension of irrigation may in time afford new and welcome opportunities for some thousands of people wishing to escape from the hazards of dry-land wheat farming or from other conditions unsatisfactory to them; may render feasible a few power developments otherwise impracticable; and may help to provide a supplemental store of water for some towns and cities now confronted with a shortage. On the other hand, overly rapid or unsound extension of irrigation can only aggravate the difficulties of many districts already in distress. The additional area that ultimately may be reclaimed through irrigation by storage and diversion of stream waters in the Missouri Basin is estimated roughly at 950,000 acres.

Kaw River bottomlands of Greater Kansas City, a view taken near the mouth of the Kaw. The Missouri is shown in the lower right corner. The crowded industrial development leaves no room, horizontally, for flood water. Making room vertically would involve raising both the levees and the bridges. Raising the bridges would necessitate raising railroad yards, streets and viaducts crossing these yards, spur tracks to various industrial

It would make some 15,800 farms averaging 60 acres each, and might support an aggregate farm population of some 75,000. The area that could be irrigated by pumping water from underground is highly conjectural. Moreover, if the amount pumped year by year in a given area where conditions initially were favorable exceeded that concurrently added to the underground supply by infiltration, the water table would be lowered correspondingly and in time would pass below the limit of profitable pumping. Even with generous allowance for indirect and intangible benefits, it is clear that the further development of irrigation cannot contribute in a large way to the general welfare of the basin.

2. *Trends and Problems:* There were approximately 4,200,000 acres of irrigated land in the Missouri Basin in 1929, about one percent more than in 1919 (see map of irrigated lands, page 74). The slight increase for the decade does not indicate that irrigation had attained a stationary condition in the Basin as a whole nor does it imply that in every irrigated area a stable and profitable adjustment to conditions of soil and climate had been established in farm practice.

In general, irrigation in the relatively arid districts in the southwestern part of the Basin is more successful than it is in the less arid districts of the northern and eastern parts. It is most successful on the Colorado Piedmont, where the amount of water needed per acre is high and where the conditions of producing and marketing sugar beets and truck crops are relatively favorable, and in some parts of the Platte River drainage area west of Grand Island, Nebraska. The irrigated acreage increased notably in portions of these districts between 1919 and 1929, but throughout both districts there has been a persistent tendency to expand unduly the acreage during periods of normal or excessive rainfall, with resulting shortage of water in times of drought.

In the northern part of the Colorado Piedmont alone the present water shortage on lands that are irrigated is estimated to average 260,000 acre-feet annually, and this figure takes no account of the water that would be required to irrigate 390,000 acres of fertile land now under the ditch there but not cultivated. The water resources of the neighboring eastern slopes of the Rocky Mountains are utilized almost completely. Small additional supplies might be obtained by impounding infrequent flood flows at great expense, but the only means of securing large supplies is by diversion from the western slopes. Shortages of water also are severe on many irrigation projects in Wyoming and western Nebraska.

The less rapid evaporation toward the north and the heavier annual rainfall toward the east reduce the dependence there of crop production on irrigation. As a consequence, many farmers on irrigation enterprises in these areas tend to employ methods of dry farming, and to abandon irrigation altogether in relatively wet years. Moreover, the temperature conditions of the growing seasons are not well suited to the production of beets and the other vegetables which are the chief cash crops in profitable enterprises in the southwest. Most projects in these areas experienced a decrease in irrigated acreage between 1919 and 1929, and first and last many projects have been abandoned and revived repeatedly.

In 1929 there were approximately 1,280,000 acres of land in the basin, located chiefly in the less dry areas, for which water was available but which were not irrigated. This excess of the acreage which could have been served over that actually irrigated is explained in large part by (1) the undeveloped fields in operating farms, (2) the incomplete settlement of many projects (the Federal projects within the basin accounted for about one-tenth of the total excess), (3) the dominance of dry-farming practices in some localities, and (4) the abandonment of a number of projects. Many active projects were operated at a loss, and great hardships characterized much of the settlement and development under way on new projects. This hardship is attributable in varying degree to (1) high per acre costs of construction, due in part to inadequate soil surveys, (2) want of suitable credit facilities, (3) lack of technical aid in making the best use of land, and (4) the fact that many settlers were without earlier experience in the exacting technique of irrigation farming.

The recent period of water shortage has accentuated the problems of irrigation in the Missouri Basin; communities in the southwestern part are suffering from lack of water for lands already irrigated, while communities in the northern and eastern parts are agitating for the building of new works or the reconstruction of abandoned ones.

3. *Specific Projects:* Further expenditures for irrigation in the Missouri Basin are desirable only if and when they will be self-liquidating investments and are accompanied by measures competent to insure profitable and continued settlement. The proposed undertakings con-

sidered by the Committee fall into three classes: Class A, those that apparently could be developed economically now; Class B, those not feasible now that may become so, however, in the near future; and Class C, those not justifiable now and not likely to become so in the near future. The placement of some projects necessarily is very tentative, because of the lack of certain data concerning them. The following table lists Class A and Class B projects; their location is shown on the accompanying project map.

Irrigation projects

Map reference no.	Project	Acreage	Construction cost	Type
	CLASS A			
12	Northern Transmountain	850,000	16,000,000	Supplemental.
13	Graybull Valley	60,000	1,108,000	Do.
14	Rock Creek	3,500	60,000	Do.
15	Wheatland	14,000	435,000	Extension.[1]
16	Lander Valley	9,200	110,000	New.[1]
17	Medicine Bow	14,300	320,000	Do.[1]
18	Buffalo Rapids	80,000	3,450,000	Do.[1]
19	Cartersville	8,100	70,000	Supplemental and extension.[1]
	CLASS B			
20	North Loup group:			
	Taschuck	7,100	301,000	New.
	Burwell	10,600	318,000	Do.
	Ord	5,900	249,000	Do.
	North Ord	8,900	300,000	Do.
21	Middle Loup group:			
	Lillian	5,000	335,200	Do.
	Middle Loup	12,200	440,200	Do.
22	Freemont Canal	64,000	1,773,000	Do.[1]
23	Paintrock	15,000	484,000	Do.[1]
24	Cambridge	6,700	535,000	Do.[1]
25	Joliet	8,000	474,000	Do.[1]
26	Harlowton	22,800	1,427,000	Do.[1]
27	Franklin	22,600	1,061,000	Do.[1]
28	Fish Creek	5,600	320,000	Do.[1]
29	Silver	7,700	365,000	Do.[1]
30	Wood's Gulch	800	57,000	Do.[1]

[1] Detailed soil and economic surveys are lacking.

5. *Recommendations:* (1) That the Federal Government, through the Bureau of Reclamation, stand ready to bear half the cost of appropriate surveys of projects that are probably feasible but concerning which data are lacking for final decision as to feasibility, provided, however, State and local agencies bear the remainder of the cost.

(2) That a Committee representing such Federal agencies as the Bureau of Reclamation, the Bureau of Agricultural Engineering, the Farm Credit Administration, and the F.E.R.A., be created to review the feasibility of projects for the construction of which Federal aid may be requested from time to time, and to cooperate in the administration of their settlement and development, if and when they are constructed.

(3) That the Federal Government participate in financing and administering such of the projects listed above as prove to be technically and economically sound on complete investigation.

(4) That the following priority in construction obtain: (*a*) appropriate supplemental works for existing projects, (*b*) suitable extensions of existing projects, (*c*) new projects of undoubted merit.

C. The Use of Water for Municipal and Domestic Purposes

1. *The General Problem:* In the headwater regions of the Missouri system and in the lower basin, below the mouth of the Platte, most cities and towns draw on surface water for their municipal supplies. In the central section, particularly in Nebraska, Iowa, and the Dakotas, the chief dependence is on wells of various depths.

The information now in hand, gathered mostly from applications to the Public Works Administration for grants and loans, discloses a large number of municipal water problems, widely scattered throughout the basin. P.W.A. grants and loans made in the Missouri Basin to date for municipal water projects total $4,944,866, and affect 114 cities and towns with a combined population of 2,075,246. Grants and loans for sewer projects total $4,343,500, and concern 55 municipalities with an aggregate population of 1,635,000. A large number of applications are still pending. The problems revealed by the P.W.A. applications are confined, for the most part, to individual municipalities. Attempts to plan regionally for the solution of municipal water problems through such means as stream regulation have thus far been hampered in most cases by a lack of detailed information. However, the Kansas State Planning Board reports that in the upper Osage Basin a number of towns, dependent on surface water for their municipal supplies, are faced with serious water shortages and with no less serious problems of pollution during periods of low flow. The situation would seem to reveal a regional problem that perhaps can be solved best through the proper regulation of streams, though data are lacking by means of which the problem or its possible solutions can be evaluated. Parts of the Colorado Piedmont and of the Plains are also confronted with pressing water-supply problems of regional scope.

2. *The Problem in the Colorado Piedmont:* In the Colorado Piedmont the existing shortage of surface water is serious at Denver and at some smaller cities as well, and it has forced these communities to look to the western slopes of the Rockies for additional supplies. Denver has applied to the Public Works Administration for a loan of $3,500,000 for the Fraser River transmountain diversion of 90,000 acre feet per year through the Moffat pilot-tunnel, and it owns water rights that give control over the potential Williams Fork diversion (25,570 A.F. per year) and the Blue River diversion (169,000 A.F. per year). It seems likely that the cluster of cities and towns near Denver may have unrecognized common interests in their water supply problems, and the possibility of a solution that would meet the needs of the group should be investigated thoroughly in connection with the contemplated Williams Fork and Blue River diversions.

3. *The Problem in North Dakota:* There has been a notable lowering in ground-water levels in the Northwest for several years, a process intensified by the recent severe and protracted drought. Very many wells that extend only a short distance below the normal level of ground water have failed, the springs have withered or gone dry, and most surface streams have ceased to flow. Some of the small bodies of impounded surface waters that remain are so polluted as to constitute a menace to public health.

Any substantial recharge of wells or increase in the ground-water discharge to streams must be preceded for some time by generous precipitation, and the shortage of water for domestic and municipal purposes and for stock has grown steadily more acute with the continuance of the drought. The possibilities of relief, apart from the replenishment of depleted supplies by nature at an uncertain time, are (1) the diversion of flood waters from the Missouri River, (2) the construction of low dams on the Sheyenne and James rivers to store the springtime run-off of those streams, and (3) the provision of new ground-water supplies by drilling wells into the deeper water-bearing formations.

(1) The Missouri River diversion project is wholly impracticable. Thus, the volume of water that could be diverted would be insignificant in comparison with the need for water; even if a vastly greater amount could be diverted, many years would pass before a large area could be benefited in any way, because of the slow rate at which ground waters percolate, and especially because the water table slopes toward the lake basin and valley depressions into which it is proposed to discharge the diverted waters; the cost of the undertaking would be excessive in view of the meager benefits reasonably to be expected; and in the judgment of reliable authorities the proposed site for the diversion dam on the Missouri River is unsuitable, while it is unlikely that an appropriate alternative site exists.

(2) A reconnaissance of the Sheyenne and James rivers by the Corps of Engineers led the Chief of Engineers to recommend a detailed survey to determine the technical and economic practicability or impracticability of constructing shallow reservoirs on them, and an allotment for the purpose has been made to the War Department by the Public Works Administration. It may be found practicable by means of storage reservoirs to provide some relief for the towns and farms in the valleys of these rivers.

(3) Nearly all of North Dakota and of South Dakota, which appears to have suffered no less than its neighbor from an acute shortage of surface and well waters, is underlain by more or less deep water-bearing formations that form great hold-over reservoirs competent to yield the needed supply of water for farms, ranches, and villages throughout most of both states. *In most localities, relief can be had by drilling wells into those formations.* Sites for drilling should be located in areas of distress by water geologists on request of the relief authorities. Where public wells are needed by small villages or groups of families, they should be located, if practicable, on school yards or other public property. If such wells are drilled on private land, the owner should be required to provide a suitable easement that would permit other citizens of his county free use of the water supply when, and so long as, the Board of County Commissioners may declare the existence of an emergency. County Relief Administrations might well be authorized to use appropriate amounts of F.E.R.A. funds to drill such wells and to provide essential pumping equipment for their use when such equipment is not otherwise available. State geologists, or their competent representatives, should give advice without charge regarding suitable sites and requisite depths for wells, proper methods of construction, and the like, to land owners contemplating drilling at their own expense and needing expert advice. The Federal Housing Administration's modernization credit plan, designed to facilitate loans to

property owners for the purpose of improving their property, might to advantage particularly encourage loans for drilling wells in drought-stricken areas.

4. *Conclusions and Recommendation:* (1) Where problems of municipal water supply are purely local in character, Federal aid, if granted, should be of the type heretofore given by the Public Works Administration.

(2) Where there is the possibility of aiding a number of municipalities through the regulation of streams, part, at least, of the cost of preliminary engineering work may properly be borne by the Federal Government. The construction cost should be allocated much as in the case of flood control, where the formation of a responsible local water district or conservancy district to bear an appropriate part of the cost is recommended as a prerequisite to Federal contribution. In principle, cooperative group action under a regional plan is worthy of active encouragement.

(3) The Fraser River transmountain diversion project is endorsed in principle.

(4) It is recommended that the Federal Government, through its appropriate agencies, vigorously encourage the drilling of wells to the deeper water-bearing formations in the drought areas of the basin, both as a means of early relief and as an "insurance" against shortage of well waters in future periods of drought.

D. The Use of Streams for Navigation

1. *Problems of Navigation:* The main stem of the Missouri River is being improved for navigation in the face of great obstacles and at an expense which has very doubtful justification. The obstacles hindering its effective development and use as a waterway include both the nature of the river itself and the nature of the transportational needs of the basin. The rather short navigation season in the middle and upper reaches of the river, the low flow in late summer and autumn (normally peak seasons in the traffic of the basin), the shifting natural channels, the unstable bottom, from which flood waters pick up here and there huge quantities of silt that are deposited at various points farther downstream, the similarly unstable banks in most places, the almost complete lack of navigable tributaries to serve as branch lines of traffic, the general direction of flow from the vicinity of Williston, N.Dak., to Kansas City, one that is directly athwart the dominant course of traffic, and the sparse population and low population-supporting capacity of most of the country along the upper reaches, are factors that restrict the commercial usefulness of the river and that make for great difficulty and great expense in attempts at its improvement.

Channel works to maintain a six-foot depth and Fort Peck Reservoir to create an eight to nine foot depth below Yankton comprise the existing project between Sioux City and the mouth of the river. The channel improvements below Kansas City are almost finished, those above Kansas City are about half completed, and construction of the Fort Peck Reservoir will require at least two more years. Work on the channel between Sioux City and Fort Benton consists merely of snagging and the maintenance of bank-protection structures. There is organized agitation, however, for the extension of substantial channel improvements farther upstream.

Fort Peck Reservoir will cost at least $86,000,000, and, in addition to improving the navigability of the river, probably will yield immediate benefits in connection with power development and flood control having a capitalized value of $10,000,000. Further expenditures may make possible ultimate power and irrigation developments with an estimated capitalized value of $40,000,000. The channel improvements above Kansas City will cost about $77,000,000, and those below that city about $80,000,000. Thus, the total construction cost for the improvements underway will not be much, if any, below $250,000,000.

Assuming that the more optimistic estimates of future traffic on the river will be realized, the savings to shippers which would result from free operation of the waterway would exceed by only a small margin the annual charge to be borne by the public for maintenance and interest on the investment. If fees were levied with a view to reimbursing the Government for the cost of maintenance only, the volume of traffic, doubtless, would be reduced materially and the savings to shippers would be vitiated in large measure. Most current estimates of prospective tonnage are exceedingly liberal, and if the present traffic on the section below Kansas City may be accepted as in any degree indicative of future prospects,[1] the probability of those estimates ever being realized even on a free waterway is very slight.

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[1] In a letter to the Secretary of War, dated September 30, 1933, the Chief of Army Engineers said: "There is practically no commercial traffic on the Missouri River at present except that incident to sand and gravel dredging and to ferry operation. The reported commerce in 1929 between the mouth and Kansas City was 1,160,000 tons and between Kansas City and Sioux City, 209,000 tons. Of this, all but 1,300 tons consisted of construction materials moved by river contractors."

Because of the rectification and stabilization of the river channel below Kansas City, the protection of the bottomlands there from lateral planation by the river and the amelioration of flood conditions have become incidental benefits. The value of the former is very considerable, and that of the latter is negligible.

The adequacy of some of the works now under construction is doubtful. The Channel below Kansas City is still unsatisfactory at several points, while the effect of Fort Peck Reservoir on low water flow in a series of dry years such as 1930–1934 would have reached or closely approached its limit.

The only tributary waterway the improvement of which has been maintained in recent years is the Osage River. It is improved for a distance of 75 miles above its mouth to a project depth of 3 feet at a total cost of $1,286,000 and is maintained at an average annual cost of $18,500. The average annual tonnage that moved on the river in the period 1928–1932, excluding construction materials for Bagnell Dam, was 1,480. Fees sufficient to reimburse the Government for the cost of maintenance alone would have amounted to $3.50 per ton-mile. Projects on the Gasconade and Yellowstone rivers were maintained at one time, but they are now curtailed or abandoned.

2. *Recommendations:* (1) That no further navigation projects in the Missouri Basin be undertaken until the present project for the improvement of the Missouri below Sioux City is completed, and its benefits, if any, have been determined.

(2) That the Osage River project be abandoned.

E. The Use of Water for Power

1. *The General Problem:* The total undeveloped water power of the Missouri Basin is about 2,110,000 kw. Six Class A projects, totalling 717,400 kw. and comprising ten plants, are listed in the accompanying table as worthy of first consideration. They were selected on the basis of the construction cost, preliminary estimates showing that they can be built for less than $150.00 per kw. Five other projects, totalling 126,000 kw. and comprising nine plants, are listed as Class B enterprises on the basis of an estimated cost ranging from $150 to $200 per installed kw. The estimates given are subject to thorough revision in the light of all relevant conditions existing when early development is contemplated. The capacity figures used necessarily are based on stream-flow measurements of insufficient duration. In all cases, further geologic investigations are needed at the dam sites.

Water-power projects

Map reference no.	Project	Number of plants	Total kilowatts	Prime kilowatts	Construction cost
	CLASS A				
1	Seminoe	3	136,000	55,800	$14,176,000
2	Elkhorn	1	11,000	4,800	1,360,000
3	Portage	1	24,000	10,500	2,871,000
4	Iliad	1	220,000	72,000	27,692,000
5	Big Horn	3	325,000	85,000	36,552,000
6	Little Horn	1	1,400	1,020	173,000
	CLASS B				
7	Pactola	1	14,676	2,430	2,701,000
8	North Platte River	4	30,600	13,000	6,082,000
9	Sutherland-Plum Creek	2	14,700	5,000	2,468,000
10	Fort Benton	1	24,000	7,350	4,180,000
11	Bearpaw	1	42,000	19,600	6,931,000

The project map for the basin shows that the potential Class A power sites are in headwater regions where, in all cases except that of the Elkhorn plant, population densities are too low to support large-scale power projects *under existing technical, social, and economic conditions.* The Elkhorn project is presented as in combination with a project for a supplemental supply of water for irrigation that is not justified under present conditions. Among the Class B projects, the Sutherland-Plum Creek sites seem not too remote from potential local markets. Applications for loans and grants to be used for constructing these plants in combination with irrigation works are now in the hands of the Public Works Administration. Any markets within usual transmission distances that may be predicted for the other potential power developments listed will probably be glutted by the output of existing plants, the Fort Peck and Casper-Alcova projects now under construction by the Government, and the large P.W.A. projects under construction or in prospect on the Platte River.

The only large-scale power project in the Missouri Basin that seems wholly feasible today on the basis of partial evidence in hand, is the so-called "Gillette Coal-Power Project", in which a steam plant at the government-owned lignite deposits of Campbell County, Wyoming, would serve the farms, towns, and industries in the Black Hills Uplift with low-cost electricity. (See also page 178.) The possibility of detailed investigation of this project, at the expense of the Federal Government and financed through the Reconstruction Finance Corporation, is now being considered.

As pointed out in the power policy section of this report, the relations between power supply and power markets are in a state of flux. Technical developments in generation and especially in transmission, changes in public policy, movements of population, shifts in cultural levels, and the like, may alter conditions rapidly and presently make feasible the development of some or all of the water-power sites listed.

The problem of the undeveloped water-power sites of the Missouri Basin is at present largely one of conservation, of exercising such Federal control over them as will permit their later development, whether by private or public interests, in a carefully planned manner calculated to promote the public welfare, rather than in haphazard fashion. Such control of the sites as the Federal Power Commission now possesses is determined, in general, by the navigability of the streams involved and the extent to which public lands are affected. The Fort Benton site is at the head of theoretical navigation on the Missouri River, but the desirability of maintaining the mythical "navigability" of the uppermost river in order to control its potential power is questionable. In view of a recent ruling of the Federal Power Commission that it has no jurisdiction over power sites on the Platte River, it seems probable that no control can be exercised by it over the other sites on the basis of the navigability of streams. However, all the reservoir sites of the upper basin include vacant public lands.

2. *Recommendations:* (1) It is recommended that no immediate further development of Missouri Basin water-power resources at Federal expense be undertaken.

(2) It is recommended, as a matter of policy and in order to preserve Federal control over power resources on lands now in Government ownership, that public lands on the reservoir sites of potential power projects in the basin be not allowed to come under private ownership.

F. The Use of Water Areas for Recreation

1. *Problems of Recreation:* The public parks and forests of the Rocky Mountain slopes furnish abundant recreational opportunities for tourists from other parts of the country as well as for the local populations, but throughout most of the Missouri Basin a tree bordered body of water suitable for swimming, boating, fishing, and picknicking is at a premium. The inhabitants of the sunburnt towns and farms of the middle plains have few or no easily accessible water bodies and forests. In the eastern part of the basin, where the total demand for recreation is greatest, there are some suitable lakes and streams in the Central Lowland and many of them on the Ozark Plateau. The facilities afforded by those in the Central Lowland have been utilized rather fully, while development of the Ozark facilities has begun only recently. In both areas there is little danger of any over development of lakes and adjacent forests for recreational use.

Throughout the Basin the supply of game preserves is likewise inadequate even for existing needs. Preserves might be useful in flood-control reservoirs which do not lend themselves to direct human use because of the range in water levels.

2. *Principles of Action:* In view of the conditions indicated, the early provision of further recreational facilities in the middle and eastern parts of the Missouri Basin is highly desirable, and so far as practicable such facilities should be regarded by the Federal Government as an essential feature of any project for the impounding of waters there for purposes of power, flood control, or irrigation. Because the benefits would be chiefly local, the role of the Government should be that of insuring the proper use of the artificial lakes and their bordering lands, rather than that of actual administration.

3. *Recommendation:* That the Federal Government through its appropriate existing agencies (The National Park Service, the Forest Service, and the Biological Survey) initiate at the proper time a survey of the recreational potentialities of each economically feasible reservoir project in which it has a financial interest, that if practicable it secure title in fee simple to the reservoir and adjacent lands where this recreational use is feasible, and that it supervise in suitable degree the administration of such lands. The state government involved should cooperate in the survey if practicable, and should administrate those lands which yield principally local benefits.

III. Project Areas

It would be possible, as a result of the study of the Missouri Basin thus far made, to suggest an order, tentatively or in some cases definitely established, in which, for example, commendable power projects, or irrigation projects, or flood-control projects might well be carried out. But even if a similar thing could be done for each type of problem associated with the use or control of water, it alone would constitute an inadequate basis for the inauguration of an effective plan for the basin. The problems of water interlock. Merely to deal with them separately would not suffice. They should be studied in the distinctive combina-

South Dakota farm affected by wind erosion in May 1934.

tions found in different parts of the basin and in association with relevant land problems.

Several areas in the Missouri Basin which lend themselves well to segregation as administrative units for multiple-purpose planning are briefly discussed below and shown on the accompanying map. It is probable that a detailed examination of the interconnected problems found in these areas would alter the values attached to several specific projects noted in preceding pages, that it would make some Class A projects appear less desirable than they seem on the basis of the methods of evaluation thus far used, or, on the other hand, increase the desirability of some Class B projects, and that it might point to the need of undertaking projects not listed at all in this report.

A. *The Ozark Highland:* The Federal Government and the states of Missouri and Arkansas should participate cooperatively in perfecting and carrying out a balanced and integrated plan for the Ozark Highland. The major objectives of such a plan are the following:

(*a*) Economic and social reconstruction.

(*b*) Provision of much needed roads.

(*c*) Withdrawal from tillage of a great body of stony and gravelly loam soils of submarginal character agriculturally that comprise the poorest class of farms in Missouri and apparently also in Arkansas, farms that in thousands of cases seem doomed under existing conditions to abandonment by their poverty-stricken owners.

(*d*) Prevention of further deterioration of large areas of rough, hilly, or mountainous land now subject to more or less serious erosion.

(*e*) Amelioration of floods and reduction of channel siltage in the lowermost Missouri and the lower Mississippi rivers through the development of an effective forest cover over much of the highland in the upper drainage areas of various tributaries.

(*f*) Amelioration of floods, regulation of stream flow, and/or development of power through storage of water, together with the development of such facilities for recreation and/or the conservation of wild life as may be combined advantageously with the operation of the reservoirs for other purposes.

(*g*) Stimulation of timber production on low-grade land near great lumber markets.

(*h*) Promotion of the recreational use and value of the Highland, an area near great population centers and remote from major parks of general interest.

B. *The Eastern Lowlands:* A general prerequisite to the successful solution of the principal water problems of the lowland portions of the eastern zone of the basin is concerted action by the respective groups of cities and towns affected by them.

The effective control of floods on the Kansas and lower Missouri rivers involves participation by states, large cities, and rural communities. Kansas City flood control requires a type of cooperation by local interests which has been lacking in the past and which deserves promotion by the Government. The shortages of water for domestic and industrial purposes which have hampered so many of the lowland municipalities in recent years will also demand a real coordination of corrective measures. A case in point is found in the Osage River Valley. The utility of the improvements for navigation that have been made in the lower Missouri will depend in large part on terminal facilities that should be provided by cooperative action of the local communities and agencies that contemplate using the river.

The fact that several governments and many interests are concerned, makes Federal aid in directive planning for such projects as the foregoing eminently desirable.

The economic considerations which are basic to effective procedure along these lines, that is, the informational bases of planning, are likewise common to most of the area. The welfare of the lowland cities, their ability to finance improvements, and their probable future growth are dependent to a considerable degree on the utilization of adjacent agricultural lands, and on the complex forces which have generated the westward shift of urban life and manufacturing in recent years. In the light of these considerations and with proper guidance, a group of cooperative programs of water use and control should be developed.

C. *The Central Plains:* Inadequate supplies of soil moisture for crops and pastures, and inadequate quantities of surface waters and of ground waters recoverable from existing wells for people and stock are fundamental aspects of most of the present economic problems of the central plains. Throughout their broad extent the major question in planning for the future is how best to use the land, in view of the present water shortage, the prospective cyclical variations in precipitation, the character of the land, and the numerous cultural factors affecting the use of the land. These plains have been an area of excessive risk in land use and while they probably never can be made one of security, the risk certainly can be reduced greatly through wise planning.

The hazards of dry-farming are especially great. The most stable aspect of life in many dry-farming districts, however, is the tenacious determination of farmers to maintain themselves in the face of recurrent crop failure. Even those settlers who depend chiefly on grazing suffer during dry years from barren pastures and lack of supplemental forage. The distress of farmers and ranchmen in periods of water shortage is reflected in the towns and cities, most of whose inhabitants depend as certainly, though indirectly, on the products of field and pasture.

As a consequence, in part, of cultivation and overgrazing, the soils over large areas of these semiarid and subhumid lands are subject to severe sheet erosion by storm waters and to erosion by strong winds. The accompanying photograph, taken in South Dakota, shows wind-swept topsoil piled high above a group of farm buildings. The drainage areas of the Kansas River and of the east-flowing tributaries of the Missouri between the mouths of the Platte and the Yellowstone are eroded badly in their drier parts, and they contribute high concentrations of silt to the troublesome Missouri.

Improvements in the dominant agricultural system and in the care of the land are problems of land use that lie, for the most part, beyond the scope of this report. It is clear, however, that there should be widespread changes in land utilization, and that effective adjustments to the available water resources and suitable measures for the use and control of water must play an important role in any successful program of land use. The difficulties of securing additional water for irrigation in this belt, as discussed in a previous section, make highly problematical the outcome of any attempts there at readjustments in farming by that means. The construction of water-supply works in some localities might only serve to strengthen for a time a social order which should be replaced. Similarly, works for flood control, hydroelectric power, or navigation might in some cases support or induce conditions opposed to long-time betterment.

Exhaustive studies of possible changes in types of farming will be necessary before profitable programs of land use in much of the central plains can be formulated. With comparatively few exceptions, Federal participation in projects for the use and control of water there should be subordinate to and an integral part of such a land-use program. By this method only will it be possible to avoid a repetition of the painful experiences of the past. The requisite studies should be pushed vigorously.

D. *The Black Hills Uplift:* Reference already has been made to the Gillette Coal-Power project (see page 174), whereby power would be generated at Gillette, Wyoming, to serve the farms, towns, and industries of the Black Hills.

Because of the nature of the consuming area, this proposal seems to afford a splendid opportunity for social betterment through the medium, in part, of an abundant supply of low-priced power. Relatively isolated, an "island" physically and culturally, the Black Hills Uplift is well suited for segregation as a planning unit. Its scenic attractions make it a recreational center of great potential value for people of the Dakotas, Nebraska, eastern Montana, and eastern Wyoming, if not of the entire country. The mineral and timber industries of the Hills, the growing number of small manufacturing industries, and the several towns within an area small enough to be served readily by motor-truck transport offer markets for the diversified agricultural products that can be grown in the area. More or less complete industrial, urban, and rural electrification seems to be an early possibility if the Gillette project proves sound and is carried out. It seems probable, moreover, that cheap power would materially aid farmers in the semiarid valleys in and beyond the foothills, by making possible the irrigation of some of their land with pumped water.

Data are lacking for a thorough evaluation of the project. The Black Hills Power District, a public corporation lately developed from a confederation of cities that had banded together for the purpose of sponsoring the project, has applied for a Federal loan of $9,225,000 for construction purposes and has asked that the Government undertake the necessary technical and social surveys under a grant of $25,000 from the Reconstruction Finance Corporation. The recommendation of the Electric Power Board of Review that the surveys be made under the proposed grant is heartily endorsed.

Federal participation in the Gillette project, if warranted by the contemplated survey, should not be confined to making the requisite loan to the applicant group under the regulations of the Public Works Administration. Here is an exceptional, if not unique, opportunity to establish a useful precedent for the formulation and execution of an integrated regional plan through the cooperative efforts of local and Federal interests. Hence it is earnestly recommended (1) that the preliminary survey, if approved, be conducted under the general direction of a subcommittee representing the various sections of the National Resources Board; (2) that the legal limitations, if any, to possible future Federal participation in the project be investigated and defined; and (3) that the final plan be developed and executed, in such degree as may prove legally possible, by a joint body of local and Federal representatives.

E. *The West Platte Basin:* Successful irrigation is the distinctive characteristic of the West Platte Basin, from the present point of view, and wise administration of surface-water resources is essential to the welfare of its people. Such shortages of water for agricultural and municipal uses as exist in the Colorado Piedmont exist also with varying intensity, at least in periods of drought, in other parts of the area.

Planning for the use and control of water in the West Platte Basin should deal conspicuously with the regulation of local streams through reservoirs, and, in some districts, with such increase in flow as may be had by means of transmountain diversions. The general problem is far too large and complex for solution by private initiative; community, state, interstate, and Federal action is needed to insure maximum stability for the population and economic activities of the area. Such agreements as the Colorado River Compact and the South Platte River Compact, dividing the waters of interstate streams between the states concerned, are valuable beginnings in the field of concerted action. Undoubtedly it will be necessary to revise existing interstate compacts from time to time, and to make new compacts, in order to keep pace with changing conditions.

F. *Northern Mountain and Plains Border:* The water problems of the Rocky Mountain slopes north of the West Platte area are in many respects similar to those of the latter, though not as urgent or as clearly defined. The administration of water resources may in the future call for interstate compacts in the northern area.

The fact that irrigation projects in the northern area have been less successful than those farther south emphasizes the need for careful planning before any extensions are made to the irrigated acreage there.

The Yellowstone River is the greatest single contributor of silt to the Missouri. An active program of erosion control along the headwaters of the Yellowstone and the Big Horn might therefore result in substantial benefits to communities on the Missouri below the mouth of the Yellowstone. Moreover, such erosion control would have an important bearing on the feasibility of all contemplated projects involving the construction of reservoirs on these rivers, since under existing conditions siltage seriously restricts the life of reservoirs in the area.

Approximately 14,000,000 acres of unreserved and unappropriated public land, largely stock range, are in or near the region under consideration. As suggested earlier in the erosion control section, the system of range management now in effect in the National Forests should be extended to these public lands, in order to check, and, to large extent, control erosion.

THE SOUTHWEST BASINS

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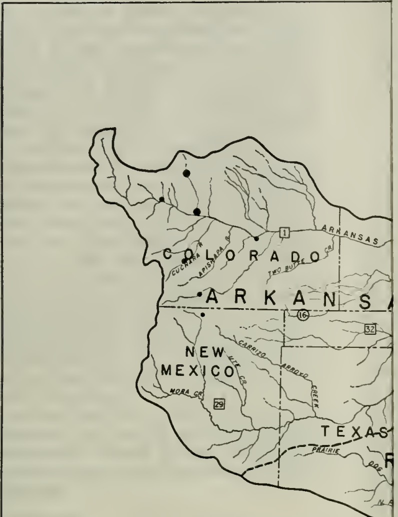
Typical Headwaters Drainage Basin on the Rocky Mountain Continental Divide.



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③ RICE IRRIGATION DIVERSION
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5 BIG SLOUGH FLOODWAY
6 GIBSON LEVEE
7 DENISON RESERVOIR
8 AUGUSTA LEVEES
9 WINFIELD LEVEES
10 ARKANSAS CITY LEVEES
11 KAW LEVEES
⑫ BRAMAN RESERVOIR
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18 TABLE ROCK DAM
19 TULSA LEVEES
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㉑ FALL RIVER RESERVOIR
22 SHOFFNER AREA LEVEES
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24 EAGLETOWN DAM
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26 MARKHAM FERRY RESERVOIR
27 FORT GIBSON RESERVOIR
28 BLAKELY MOUNTAIN DAM
29 CONCHAS RESERVOIR
30 REMMEL DAM
31 MURDOCK RESERVOIR
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33 NORTH BOSSIER EXTENSION L
34 FORT SUPPLY RESERVOIR
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39 CADDO LAKE DAM
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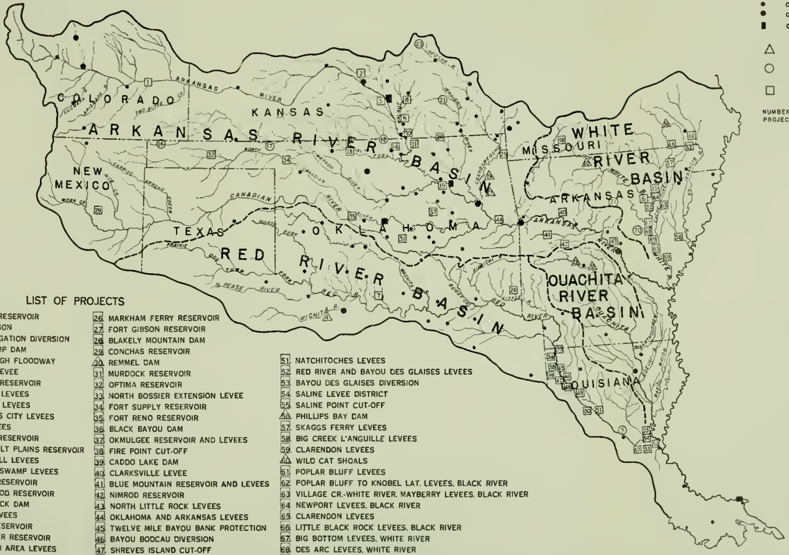
NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE

SOUTHWEST BASIN INDEX AND PROJECT MAP

LEGEND

- ● CITY 5000 TO 25000 INHABITANTS
- ● CITY 25000 TO 100000 INHABITANTS
- ▮ CITY OVER 100000 INHABITANTS
- △ POWER PROJECTS
- ○ IRRIGATION PROJECTS AND WATER SUPPLY PROJECTS
- □ FLOOD CONTROL PROJECTS

NUMBERS WITHIN SYMBOLS REFER TO PROJECT TABULATIONS



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58 BIG CREEK L'ANGUILLE LEVEES
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61 POPLAR BLUFF LEVEES
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63 VILLAGE CR.-WHITE RIVER, MAYBERRY LEVEES, BLACK RIVER
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69 DE VALL'S BLUFF LEVEES, WHITE RIVER
(70) GREER'S FERRY RESERVOIR, WHITE RIVER
(71) GRAND PRAIRIE GRAVITY SYSTEM, WHITE RIVER

I. General Descriptions

The Southwest Basins, comprising four principal rivers and their tributaries, present for study 280,000 square miles of land, mostly fertile, possessed of varied natural resources, and capable of extensive development. As agriculture and industry are developed in the basins, their population, now comparatively sparce, will increase correspondingly.

As the rivers of the Southwestern region flow from their mountain sources in a southeasterly direction, they pass successively through precipitous rocky canyons, desert plateaus, agricultural lands, and forest areas. Finally their waters are delivered into the rich alluvial valley of the lower Mississippi. The steep gradients of the rivers in their upper reaches, while aggravating conditions that make for floods, at the same time afford opportunities for hydro-electric power development that sooner or later will play an important part in the life of the region.

The Southwest is a promising field for local initiative in flood control and water resources development. Liberal Federal participation would of course, greatly stimulate prosecution of the work.

II. Conclusions

Data concerning the individual projects have been obtained largely from the 308 reports. These data were supplemented by information contained in applications to the Public Works Administration.

In the comparatively short time so far available to the Mississippi Valley Committee, it has been impossible to verify estimates in detail or to make extended field surveys. Much research is needed before many individual projects can be recommended for actual construction, but the information at hand is sufficient for preliminary purposes, including initial comparisons of one project with another. It will serve to indicate immediate economic and social benefits associated with the projects and to show in general how a particular project would contribute to the improvement of the entire area in which it is located. The attempt is made to present the background necessary to the formulation of a comprehensive plan.

By selective processes all of the projects proposed have been divided into three groups:

Class A—Projects which appear to be economically justified by the benefits to be derived from their construction. Also certain projects which, although perhaps lacking to some degree in economic justification, are exigent in character and the construction of which may avert destruction of life.

Class B—Projects which lack immediate justification for construction but which are of sufficient importance for inclusion in a comprehensive program and the need for which will apparently develop in the future.

Class C—Projects having insufficient merit to warrant further consideration by the Committee. Further reference to them is not made in this report.

No attempt has been made to set up an order of preference in any one group. Before the program can be finally executed, conditions will inevitably change, altering at least in part, any order of priority which may seem initially desirable.

III. Recommendations

The following projects are selected for inclusion in the general program as Class A or Class B, and are enumerated in each class in order of their location downstream along the main stems of the principal rivers and their tributaries. The purpose for which each project is proposed is designated by F for flood control, P=Power, N=Navigation, I=Irrigation, W=Water Supply, R=Recreation.

RED RIVER

Class A Projects

	Cost
Lake Kemp Dam, Wichita River—P	$170,000
Black Bayou Dam, Black Bayou—F	125,000
Bayou Bodcau Diversion, Bayou Bodcau—F	1,893,000
Wallace Lake Dam, Bayou Pierre—F	400,000
Red River Parish Levees, Red River—F	180,000
Bayou Pierre Ditch, Bayou Pierre—F	300,000
Natchitoches Levees, Red River—F	355,000
Saline Point Cut-off, Red River—F	67,000
Bayou des Glaises, Diversion, Bayou des Glaises—F	285,000

Class B Projects

Denison Reservoir, Red River—F, P, N	40,000,000
Eagletown Dam, Mountain Fork River—F, P, N	5,784,000
No. Bossier Extension Levee, Red River—F	210,000
Fire Point Cut-off, Red River—F	160,000
Caddo Lake Dam, Cypress Creek—F	600,000
Twelve Mile Bayou Bank Protection—F	49,700
Shreves Island Cut-off, Red River—F	60,000
Saline Levee District, Red River—F	174,000
Red River & Bayou des Claises levees, Red River—F	825,000
Rice Irrigation Diversion—I	10,000,000

ARKANSAS RIVER

Class A Projects

	Cost
Caddoa Reservoir, Arkansas River—F, I	$7, 981, 000
Augusta, Kansas, levees, Arkansas River—F	77, 800
Winfield, Kansas, Levees, Arkansas River—F	108, 630
Arkansas City, Kansas, levees, Arkansas River—F	94, 000
Kaw, Oklahoma, levees, Arkansas River—F	32, 500
Great Salt Plains Reservoir, Salt Fork—F, R	1, 233, 000
Tulsa Levees, Arkansas River—F	308, 000
Pensacola Reservoir, Grand (Neosho) River—P, R	13, 290, 000
Conchas Reservoir, So. Canadian River—F, I, W	8, 925, 000
Fort Reno Reservoir, No. Canadian River—W, F, R	6, 032, 000
Clarksville levee, Arkansas, Arkansas River—F	70, 000
Oklahoma and Arkansas levees, Arkansas River—F	82, 500

Class B Projects

Hutchinson, Kansas, levees—F	1, 568, 600
Big Slough (Wichita, Kansas) Floodway—F	3, 585, 000
Braman Reservoir, Salt Fork River—W, R	348, 800
Blackwell, Okla., Levees, Salt Fork River—F	50, 000
Kenton Reservoir, Cimmarron River—I	2, 423, 000
Englewood Reservoir, Cimmarron River—I	4, 148, 000
Hulah Reservoir, North Caney Cr.—F, W, R	2, 423, 000
Fall River Reservoir, Verdigris River—W	1, 275, 900
Council Grove Reservoir, Grand (Neosho)—W, R	1, 330, 000
Markham Ferry Reservoir, Grant (Neosho)—P, R	4, 712, 000
Fort Gibson Reservoir, Grand (Neosho)—P, R	6, 511, 000
Mardock Reservoir, Little River—F, R	939, 600
Optima Reservoir, North Canadian River—F	1, 530, 000
Ft. Supply Reservoir, North Canadian River—F	2, 585, 000
Okmulgee Reservoir and Levees, Deep Fork River—F	5, 260, 000
Blue Mt. Reservoir & Levees, Petit Jean River—F	1, 489, 600
Nimrod Reservoir, Fourche LaFave River—F	1, 093, 800
North Little Rock and Levees, Arkansas River—F	400, 000

WHITE RIVER

Class A Projects

Table Rock Dam, White River—P, F	14, 286, 000
Phillips Bay Dam—Current River, P	2, 294, 000
Skaggs Ferry Levees—Black River, F	80, 100
Big Creek-L'Anguille Levees—L'Anguille, F	148, 500
Clarendon Levees—White River, F	326, 900

Class B Projects

	Cost
Wild Cat Shoals Dam, White River—P	$23, 253, 000
Poplar Bluff Levees, Black River—F	756, 300
Poplar Bluff to Knobel Lat. Levees, Black River—F	2, 604, 000
Village Cr.—White River, Mayberry Levees, Black River, F	1, 153, 800
Newport Levees—Black River, F	161, 100
Clarendon-Lambrook Levees, White River—F	4, 846, 600
Little Black Rock Levees, Black River—F	820, 000
Big Bottom Levees, White River—F	148, 500
Gibson Levee, White River—F	24, 000
Cypress Swamp Levees, White River—F	25, 000
Shoffner Area Levees, White River—F	63, 000
Des Arc Levees, White River—F	49, 900
De Vall's Bluff Levees, White River—F	9, 000
Greer's Ferry Reservoir, White River—I	2, 000, 000
Grand Prairie Gravity System, White River—I	6, 200, 000

OUACHITA RIVER

Class B Projects

Blakely Mountain Dam and Power Plant, Ouachita River—P, F	13, 440, 000
Remmel Dam, addition to Power Plant, Ouachita River—P	760, 000

IV. Natural Features

1. *Size and Physical Characteristics:* The Southwest Basins constitute almost one-quarter of the area of the entire Mississippi River Basin. The physical characteristics of the several rivers are so diversified that they cannot be well set forth in a brief general description. For this reason they have been tabulated separately in Table 1.

The topography of the regions through which these rivers flow varies from mountainous areas with steep declivities to agricultural plains and low-lying bottom lands. An examination of the table referred to will show that protection by levee construction or otherwise is needed in the lower reaches of all the rivers, with the exception of the Ouachita, while the upper reaches of the White and parts of the Arkansas Rivers in particular present attractive possibilities for electric-power development.

2. *Water Resources:* The average annual precipitation in the Southwest Basins ranges from 11 inches in Eastern Colorado to more than 52 inches in Louisiana. It increases progressively from West to East. Rainfall records of the United States Weather Bureau are available for parts of the basins. The stations are few and unevenly distributed. Additional rainfall and stream gaging stations are desirable in order that adequate data may be obtained. Such data is essential to the planning for protection against floods as well as for utilization of the streams for power, irrigation, and other pur-

TABLE 1

CHARACTERISTICS OF THE RED RIVER

Name of stream	Length in miles	Drainage area in square miles	Fall in feet per mile	Average annual rainfall	Run-off (maximum)	Terrain [1]
				Inches		
Main Stem	1,315	66,680		35	228,000	
Prairie Dog Town Fork	300	10,600	3.9	23		F.
Red River (W. Okla.)	260	27,800	2.2-1.6	28		F, R.
Red River (E. Okla.)	290	12,400	1.2-0.8	38	300,000	R, T.
Red River (La. Sec.)	345	15,100	.6-4	50	260,000	F, S, T.
Red River (Backwater)	120	700	.04-4	52	210,000	F, S, T.
Tributaries:						
North Fork, Red. R. (Mi. 1018 upstream)	210	4,750	3 -4	25		F.
Pease R. (Mi. 1005)	160	3,400	2 -2.5	25		R, F.
Wichita R. (Mi. 944)	230	3,400	2.5 -3	28		R, F.
Little Wichita R. (Mi. 911)	80	1,500	2.5	30		R, F.
Washita R. (Mi. 799)	500	7,800	2 -2.5	33		R, F.
Blue R. (Mi. 689)	100	660	4 -5	38		R.
Boggy R. (Mi. 660)	110	2,500	1.1 -2	43		40% T, M; 60% R.
Kiamichi R. (Mi. 627)	160	1,700	.4 -8	44		T, M, R.
Little R. (Mi. 466)	210	4,100	.8 -1	46		75% T, M; 25% R.
Sulpher R. (Mi. 379)	290	4,000	.4 - .5	48		R.
Cypress Cr. (Mi. 307)	130	3,500	1 -1.2	48		T, F, S.
Bayou Dorcheat (Mi. 265)	120	1,400	.5 - .8	49		T, S.

CHARACTERISTICS OF THE ARKANSAS RIVER

Name of stream	Length in miles	Drainage area in square miles	Fall in feet per mile	Average annual rainfall	Run-off (maximum)	Terrain [1]
Main Stem	1,450	160,500				
At Pueblo		4,820	40	12	103,000	M.
At Hutchinson		38,540	6.9	26	150,000	F.
At Tulsa		74,600	3.2	39	244,000	F, R.
At Ft. Smith		149,900	1	39	552,000	R, T.
At Little Rock		157,900	.8	49	830,000	R, M, T
At Mouth		160,500	.6	51	813,000	S, F, T.
Tributaries:						
Little Arkansas R		1,355		26-30		R.
Ninnescah R		2,205		23-31		R.
Walnut R		1,980		30-32		R.
Salt Fork R	192	6,700	10.1	22-34	110,000	F, R, E.
Cimmarron R	600	18,060	20	16-34	80,000	F, R, E.
Verdigris R	340	8,150	9	34-40	80,300	F, R, E.
Grand (Neosho) R	460	12,660	1.5	40-43	300,000	R, M, T.
Illinois R	145	1,620	8	39-42	120,000	R, M, T.
N. Canadian R	800	14,310	7.2	18-38	100,000	F, M, E.
S. Canadian R	900	29,700	10	17-38	200,000	F, R, M, E.
Little R	90	950		29	450,000	K, ¼ T, E.
Poteau R	128	1,895	2.9	39-44	70,000	R, M, T, E.
Petit Jean R	113	1,080	5.2	44	48,000	R, M, T, E.
Fourche LaFave R	140	1,125	14 2	47	85,000	R, M, T, E.

CHARACTERISTICS OF THE WHITE RIVER

Name of stream	Length in miles	Drainage area in square miles	Fall in feet per mile	Average annual rainfall	Run-off (maximum)	Terrain [1]
White River	690	8,300	4.4	46	440,000	
White River and Tributaries	1,740	20,000				
James River	60	1,490		43		M, T.
Buffalo Fork	100	1,410		47		M, T.
North Fork	60	1,780		45		M, T, S, F.
Black River	300	8,680	0.6	47	200,000	H, T.
Village Creek	40	310		48		F, S, T.
Little Red River	93	1,850		48		H, T.
Bayou Des Arc	45	650		50		F, S, T.
Cache River	100	2,050	0.5	50		F, S, T.
Big Creek	45	910		52		F, S, T.
Bayou Lagrue	50	580		52		F, S, T.
Current River	140	2,860	3	46	34,000	H, T.
Fourche Creek	25	280		47		H, T.
Spring River	50	1,280		47		H, T.
Eleven Point River	90	1,050		46		H, T.
Strawberry River	55	720		46	33,000	H, T.
Black River	300	2,490	1.3	47	95,000	H, F, S, T

CHARACTERISTICS OF THE OUACHITA RIVER

Name of stream	Length in miles	Drainage area in square miles	Fall in feet per mile	Average annual rainfall	Run-off (maximum)	Terrain [1]
Main Stem	605	24,790		50	100,000	
Headwaters, Ouachita R	158	1,540	12-3	52	200,000	M., T.
Caddo River	78	490	2		50,000	M.
Little Missouri R	130	2,080			100,000	M., H.
Smackover Creek		580				H.
More Creek		570	0.3			H.
Saline River	215	3,270		45	61,500	H., M.
Bayou Bartholomew	340	1,860			25,000	56% H., F., S.
Bayou D'Arbonne	90	2,330	.16		30,000	H.
Boef River	240	2,340			15,000	F., H., S.
Tensas River	315	3,600			20,000	F., S.
Little River	174	2,820		52	20,000	H.

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[1] T = Timbered, M = Mountain, H = Hill, F = Flat, S = Swampy, R = Rolling, E = Eroding.

poses. Along the 99th meridian there is a fairly well defined zone of transition between the semi-arid western plains, where irrigation and dry farming are established practices and the wet farming country of the lower elevations. Rainfall dependability increases with the annual precipitation. Variations from the mean are generally greater both in number and magnitude as aridity increases.

These general observations regarding rainfall are equally applicable to its resulting run-off. Streams are flashy in their higher elevations. As the tributaries progressively contribute their volumes of water to the main streams, the need for flood protection by levees, channel improvements, spillways, or reservoirs becomes increasingly great.

Comparatively few data have been accumulated in the past regarding the subsurface water in these basins. Investigations should be carried on much more intensively in order that they may supply reliable data for a long-term program whereby the water table can be maintained. The subject is even now of importance notably in the rice fields of the lower basins where the deficiency of ground water calls for surface storage reservoirs for purposes of irrigation. This will relieve the over-draft on the underground water supply.

Each of the four basins may roughly be divided into two parts for the purpose of water planning. In the upper parts, the problem is mainly one of conservation and augmentation. There stream flow is inadequate to maintain the future, or even the present, needs of the region. Conservation by storage reservoirs becomes a necessity, and transmountain diversions from the western slopes of the Rockies to the headwaters of the Arkansas are essential factors in its future development. In the lower parts of all four basins, the scene changes. Control and utilization of excess water become paramount on all these rivers. Flood control, power development, and perhaps the regulation of low flows for navigation constitute the main problems.

3. *Natural Vegetation:* Natural vegetation runs the gamut from desert sagebrush and cactus in the headwater regions of the Red and Arkansas Rivers through the long grass of the Central Plains, the short grass between the 99th and 100th meridians, to extensive growths of forests along the lower reaches.

4. *Mineral Resources:* The Southwestern Basins are rich in mineral resources. These include the gold and silver deposits of Colorado, the lead and zinc of the Joplin mining district, the bauxite, iron, marble, novaculite, fire clays, limestone, and other resources, principally to be found in the Arkansas Basin. Petroleum and its products have proved to be a most valuable discovery in these basins. Production from this source reaches an enormous value which will be instrumental in developing the country.

V. Social and Economic Conditions

1. *Population:* The populations of the four basins are tabulated as follows:

	1920	1930
Red River Basin	2,400,000	2,700,000
Arkansas River Basin	3,510,000	3,937,000
White River Basin	700,000	821,000
Ouachita River Basin	725,000	818,000
	7,335,000	8,276,000

A glance at these figures will show that the region as a whole is experiencing a steady increase in growth of population. With the development of industries, the provision of cheap power and the protection of the land against floods there should result an inflow of settlers, attracted by the better living conditions and the opportunity for development of natural resources. Nearly half of the population lives on farms. Relative rates of increase and decrease of population are shown in the maps. The discoveries of new oil fields and in some cases the exhaustion of older fields have caused violent fluctuations in the smaller units of population. The depletion of timber in some of the foothill lands of the Alluvial Valley has also resulted in a shift in residence.

Of the 650,000 farms in the basins, 5 percent have electric lights, 25 percent have telephones, 11 percent have radios, 51 percent have automobiles, and 6 percent have water piped to the houses.

Aside from such centers as Tulsa, Oklahoma City, Wichita, Little Rock, and Shreveport, no large cities exist in these basins. The cities are for the most part distributing points of agriculture and industry, and their sites have been as a rule determined by the main arteries of traffic, principally railroads. The entire region is well supplied with railway and highway transportation. For the present at least, nothing is to be recommended in the way of further development along these lines.

2. *Land Use.*—Due to differences of topography and character of soils, the use of land varies considerably in the different basins.

(*a*) *Red River.*—With the exception of the nonirrigated headwater area where dry farming is precarious, if not impracticable, there are productive farm lands all along the Red River Valley. In northwestern Texas and southwestern Oklahoma the principal crops are cotton and corn, the former reaching a production as high as 2,000,000 bales per year. Forage and small crops, fruits and garden truck are also raised. Rice culture is profitable in the lower valley. The entire Red River Basin is well adapted to stock raising, which is carried on almost to the exclusion of agriculture on some of the upper headwater areas. Cattle in the Texas Panhandle, mules, horses, cattle and hogs in Oklahoma, consume much of the feed crops produced.

(*b*) Arkansas River—It has been said that practically all temperate-zone crops grow in the Arkansas Basin. In the mountainous headwater areas, above the five-thousand-foot contour, crops are generally limited to native hay, field peas, and lettuce. Bearing eastward, across the Colorado Piedmont and into the Great Plains, in the bottomlands are found diversified crops produced by irrigation; alfalfa, sugar beets, melons, and fruits. Dry farming in the semiarid uplands of the Great Plains produces wheat crops about once every three years. Livestock here assumes importance. In the Texas Panhandle, however, ranching, once apparently firmly established, is steadily giving way to crop farming.

East of the wheat belt are the corn and cotton areas, the former predominating in Kansas, the latter in the weevil-free section of southwestern Oklahoma, where agriculture has been practiced for only about a quarter of a century. Both areas are combined in the alluvial valley of the Arkansas where the soil is very rich.

Of particular interest in the Arkansas Valley is the northern limit of the cotton belt. Here it is more than a secondary crop; it is a boundary of cultures where north and south meet.

Grazing in the Rocky Mountain National forests provides summer feeding for cattle and sheep, the latter being kept in the higher altitudes. Practically all of the Basin east of Central Kansas is well suited to stockraising in combination with diversified farming, while in the West stockraising exclusive of agriculture is carried on over large plains areas.

(*c*) White and Ouachita River Basins—The White River Basin is essentially an agricultural region, producing all truck crops and some grain, cotton and rice. Diversified farming on a small scale is extensively practiced. The soils of the valley, eroded from the hillsides of the Ozarks, consist of water-carried top soils intermixed with glacial drift, with resulting nonuniform fertility.

In the Ouachita Valley cotton and corn predominate, but because of the dense growth of pine in the mountains and hardwood in the lowlands, the region as a whole is only farmed to a small extent. The territory includes much cut-over land.

Stock raising in both these valleys is limited to normal stocking of the diversified farms and plantations.

3. *Industries:* The value of industrial products is much less than that of agriculture. The principal industries are those utilizing petroleum, cotton, and timber products. They are located at strategic points throughout the basins and constitute the principal source of revenue outside of agriculture. Manufacturing is concentrated in the cities, but, because of the high freight rates, there is an economic demand for local industries, distributed among the smaller communities, to utilize home products and prepare them for local consumption.

VI. Control and Use of Water Resources

The Red River Basin

The Red River is subject to very large floods which originate either in the headwater area or on the tributaries and become a serious menace to the valley after passing Denison, particularly below Shreveport. The maximum stage at Shreveport during the past 50 years was 45.9 feet (1882); a stage of 42.35 feet was recorded at Alexandria in 1927. The Red River has contributed as much as seven percent of the peak flow of the Mississippi River.

The rich valley lands are in constant danger of floods. At present 600,000 acres are protected by levees and about 500,000 acres can be protected by additional levees, combined with some channel improvements and reservoirs. Another 1,000,000 acres subject to inundation are likely to remain unprotected because of location and the cost ot protection. Up to the present the United States Government has spent over $325,000 on flood control in the backwater area of the Red River. Local landowners have expended $10,000,000 on levees, many of which have later been washed out or have become inadequate.

Under existing agricultural conditions it is impossible for the local districts to obtain further financing and in some cases even to maintain payment of interest on their bonded indebtedness. They are faced with the alternative of Federal aid or of entire abandonment of improved properties.

Losses resulting from periodic flooding of 1,600,000 acres along the main river have exceeded $10,000,000. Also subject to floods are 1,700,000 acres on the tributaries and 1,700,000 acres in the backwater area.

Levees along the Red River below Shreveport have become practically continuous. For this reason the disposal of drainage from the hills behind the levees has become a problem second only to that of floods from the main river. This will require either larger drains through the levees where borrow pits are not available or relief outlets at strategic points.

The reservoirs constructed on the main stem should be designed to allow for silting. However, the accumulation of silt in such a reservoir as Denison doubtless would not seriously impair its capacity for many years. The silt load, the color of which gave the Red River its name, has been increasing during the past half century as cultivation has increased erosion, but much of this silt is deposited along the changing stream bed and never reaches the Mississippi or the Gulf.

The Mississippi River flood crest could be reduced by about nine inches by the construction of the key reservoir at Denison, and reduced another foot by the provision of additional storage on the main stem and tributaries below Denison at a cost exceeding $15,000,000.

2. *Power:* If all the projects considered were constructed, it would be possible to develop 600,000 horse power on the Red River and tributaries. In this drainage basin, hydroelectric power must compete with cheap steam power produced from gas, oil or coal at costs as low as three mills per K.W. hr.

There are now only three hydro power plants in the Red River Basin. They are located at Chickasha, Anadarka and Carnegie. They are all on the Washita River and their aggregate installation is 1,775 K.W.

Future demands for electrical energy lie primarily in the expansion of use in communities now served. The inhabitants of the hill country are not financially able to use power extensively nor are there any large mining or industrial demands aside from those of the petroleum industry.

3. *Irrigation and Drainage:* There are two types of irrigation in and near the Red River Basin. The watering of more than 600,000 acres of land for rice culture in Louisiana, Arkansas and Eastern Texas, and the watering of dry lands in western Oklahoma.

At present the rice lands in Southern Louisiana are watered by pumping from underground sources. The depletion of this supply with consequent increase in pumping costs brings about a need for supply from surface water sources.

Irrigation of the semiarid country is a more remote problem than that of rice lands. However, its solution should not be ignored. Supplemental storage sufficient to insure an adequate water supply for existing irrigated acreage is preferable to increasing acreage under irrigation. Below irrigation bench lands some drainage will eventually be necessary.

Drainage of the lowlands along the Red River in Louisiana, with malaria and mosquito control has been recommended by the State Board of Control because of recent increase in malaria mortality from 6.3 per one hundred thousand population in 1931 to 19.4 in 1932.

Drainage of the valley lands behind levees must be included in any comprehensive plan for flood control. There are large areas of cypress swamps as well as lowlands in the backwater area which can never be economically drained.

4. *Navigation:* Notwithstanding the fact that since 1828 the Red River has been designated as navigable for 550 miles above the mouth, or to the Arkansas-Oklahoma state line, the fact remains that there is no actual navigation above Alexandria, Louisiana, 122 miles from the Mississippi. Total tonnage in 1931 amounted to only 26,000, which consisted largely of sand, gravel, and freight for levee construction. While there is considerable cotton and lumber to be moved out of the Red River Basin, return water-borne freight is not available. As a result river navigation which was in the antebellum days an important factor in the development of the southwest and in the growth of such communities as Alexandria and Shreveport, has been virtually supplanted by rail and highway transportation.

The Red River, being a very unstable and heavy silt carrying stream, is difficult to keep open for navigation. Locks would silt and channels shift. Canalization, bank protection, and regulation of flow can be combined to maintain a six to nine foot navigation channel, but the cost, it is estimated, would be about

15 times greater than the probable benefits. Expenditures for navigation purposes on the Red River are not justified except in a few localities.

The Arkansas River Basin

1. *Flood control:* The channel of the Arkansas River is, in general, capable of carrying less than half of its maximum flood flows. Destructive floods are frequent and especially varied in character.

Along the main stem, 1,496,000 acres of land are subject to overflow. On the tributaries having major flood problems, there are 2,350,000 acres additional or a total for the basin of 3,846,000 acres. The average annual direct damage for the entire main stem is about $1,000,000, the maximum for any one year being estimated at about $15,000,000. The figure for the average annual loss, however, is probably subject to revision when a uniform policy of evaluating damages is evolved.

Existing flood-protection works in the upper Arkansas basin are confined mainly to cities and show varying degrees of adequacy. Below Fort Smith flood-protection works consist almost entirely of levees, of which there are some 180 miles. These levees are included in 26 levee or drainage districts and were constructed at a cost of some $2,960,000, giving protection only against Arkansas River waters. They vary widely in height and cross-sectional dimensions and inadequately protect some 672,700 acres, of which 220,000 acres are in the Mississippi backwater area. During the flood of April 1927 all the levee systems below Fort Smith failed, with the exception of the New Gascony levee which held because of the relief obtained through the failure of other levees.

Existing protection works are becoming progressively inadequate. Cultural development in the basin is increasing the run-off rate, with the result that flood hazards are continually growing. Not only is the denuding of the watersheds a contributing factor, but so are also the drainage works along highways and in urban centers.

2. *Power:* The principal function of new power developments in this basin at present is to serve the growing needs of existing systems rather than to serve new markets. The apparent scarcity in certain regions coincides, as usual, with relatively low population densities.

At present there are no water-power installations along the main stem of the Arkansas. The natural gas, oils, and cheap coal that are abundant in the basin produce the present power and any new hydroelectric project will find competition in existing and potential steam and natural-gas installations.

3. *Irrigation:* An idea of the varying extent of irrigated lands in the basin may be gained from the table below:

State	Irrigated lands in Arkansas basin			
	Area irrigated 1929	Area irrigated 1919	Area enterprises were capable of supplying with water, 1930	Irrigable areas in enterprises, 1930
	Acres	*Acres*		
Colorado	558, 072	641, 476	690, 955	762, 208
New Mexico	71, 716	90, 185	113, 142	119, 887
Texas	466	440	766	766
Oklahoma	950	2, 843	5, 974	5, 987
Kansas	69, 879	46, 539	81, 177	91, 361
Arkansas	52, 446	63, 521	68, 608	71, 754
Total	753, 533	845, 004	960, 622	1, 051, 963

There is a need for supplemental water projects, provided soil surveys of the irrigable lands show high fertility and desirable classification as to character and topography.

4. *Navigation:* Up to the beginning of the present century navigation was active on the lower reaches of the Arkansas River. At one time some 13 registered steamers were engaged in freight movements. In addition forest products were rafted down the river prior to the gradual depletion of timbered areas. The traffic reached its peak in 1907, when 104,593 tons, valued at over $2,000,000, were shipped. As a result of various factors these movements of package freight and forest products have of recent years practically disappeared from the river. However, some 577,000 tons of sand and gravel were hauled locally for short distances (generally less than three or four miles) in 1931.

The legal head of navigation is at present considered to be the mouth of the Neosho (Grand) River, 465 miles above the mouth of the Arkansas. However, except for the local sand and gravel movements centered at Ozark, Dardanella, Little Rock, and Pine Bluff, no commerce exists upstream from the latter point (117 miles above the mouth), and less than 6,000 tons of commercial freight moved below that point in 1931.

Between 1832 and 1931 a total of $4,220,000 was expended by the Federal Government for navigation improvements on the Arkansas River. The major portion of this sum was spent prior to the adoption of the present project in 1902. Comparatively small sums have been expended since 1916. For the past seven

North Canadian River Will Flood Oklahoma City until Fort Reno Dam Is Constructed years these have averaged about $30,000 annually, largely spent for the removal of snags in the used portion of the river below Pine Bluff.

Various navigation projects have been proposed by local interests. The most extensive would provide a nine-foot channel from the mouth to Tulsa, Oklahoma, at an estimated cost of over $200,000,000. The expenditure of such a sum, or any other large sum, for the purpose of improving this stream for navigation appears to be without adequate economic justification.

The White River Basin

1. *Flood Control:* A large area in the lower White River Basin is subject to Mississippi River backwater overflow.

Levees to protect 1,200,000 acres of land have been constructed in a haphazard way by some 20 levee districts for about 270 miles along the river bottoms. The contract cost of levees and drainage ditches amounts to $15,700,000, in which is included $10,000,000 for Mississippi River main line levees from Helena southward with the result that there is no effective or dependable levee system on White River to handle the larger floods. Including drainage and levees, 87 improvement districts have been formed, but their physical and financial condition is deplorable as a result of floods and partly due to failure of unimproved acreage to contribute to costs.

An additional 146,000 acres, 60,000 of which lie within the backwater area, can be protected by levees at a cost that is economically justified.

The estimated value of all property in the overflow area of 1927 was $64,000,000. Losses were estimated at $18,000,000.

Reduction in flood heights by means of reservoirs, some of which can also provide power storage, is considered feasible to a limited extent. Local protection by levees will be required to supplement reservoirs. Due to the comparatively narrow channel, which easily overflows, channel improvement alone is not effective on this stream.

Partial protection can be afforded to several hundred thousand acres through the consummation of a coordinated program of levee and reservoir construction. Various estimates place the cost of such protection at between $25 and $30 per acre of land.

The effect upon the Mississippi River of flood control by means of reservoirs on the White River would not be great, probably not reducing the flood crests in the former by more than 200,000 second-feet. The cost of reducing the maximum stage of the Mississippi by several feet under conditions similar to 1927 seems to be prohibitive.

2. *Power:*—Power development is highly important on the White River. There are numerous valuable hydroelectric power sites in the mountains, which could be developed to meet future demands. It has been estimated that approximately three-quarters of a million horsepower can ultimately be developed.

At the present time there are hydroelectric power developments aggregating 12,000 kva on the White River, the Empire District Electric Company Ozark Beach Plant being the principal installation.

Existing markets in the lead belt, in St. Louis, Missouri, and in Arkansas can be served most advantageously by interconnections between hydro and steam plants. Electrification of railroads through the Ozarks and electrolytic ore reduction processes may offer new markets.

Utilization of the upper portions of some of the power reservoirs for the storage of flood waters is possible and can be made of value to comprehensive flood control without unduly penalizing the power production.

3. *Irrigation and Drainage:* The irrigation problem on the White River is local and minor in character. Only one project for this purpose has been included. This project provides for the irrigation from surface water sources of more than 100,000 acres of rice lands in the Grand Prairie region of Arkansas, as a substitute for the rapidly diminishing well-water supply. This supply has already been depleted 20 percent, causing a corresponding increase in pumping rates that are already approaching prohibitive limits. It has been estimated that an irrigation supply can effect an annual saving in present annual pumping costs of more than $7 per acre.

4. *Navigation:* Water-borne traffic on the White River is limited to 331 miles on the main stem, 213 miles on the Black River and 94 miles on the Current River. The cost of increasing the channel depths is not justified, except as a byproduct of flood control or power development, for only 240,000 tons are carried on the river annually and existing navigation needs are being provided for at present. The Federal Government has expended about $1,900,000 for open-channel work on the three rivers of the White River System, and about $2,000,000 for locks and dams on White River, or a total of $3,900,000 for navigation improvement.

The Ouachita River Basin

1. *Flood Control:* Backwater from the Mississippi and Red Rivers, as well as overflow from the Arkansas River and Mississippi River, threatens the lower valley of the Ouachita in addition to floods from the Ouachita itself. In 1927, 47,000 acres of cleared land and 180,000 acres of timber land were inundated. The "Adopted Plan" of the Mississippi River Commission provides flood protection for 2,600 square miles, principally by ring and guide levees which appears to be all that is justified at present. Super floods will flow through the Boeuf spillway, 2,700 square miles of which would be under backwater during high flood peaks. The extensive timbered areas preclude the possibility of complete levee protection on an economical basis because they cannot contribute enough to the costs.

Storage reservoirs at Blakely Mountain on the Ouachita Rivers as well as on the Caddo and Little Missouri rivers with a total capacity of 747,000 acre-feet would equalize a considerable amount of the flood flow at a cost of $8,000,000. Combined power and flood control reservoirs at Blakely Mountain Dam and Remmel Dam would give full protection to the section between Malvern and the mouth of Caddo River and partial protection from there to Arkadelphia.

All the reservoir projects contemplated or proposed for flood control would cost approximately $45,000,000. Their combined effect in operation would not reduce the Mississippi River flood crest more than nine inches.

3. *Power:* Potential power developments are located in the mountain sections of the Ouachita Basin. The most important is the Blakely Mountain project on the main stream near Hot Springs, Arkansas. In combination with this there are possible additions to the existing Remmel and Carpenter installations.

There are three dam sites on the Caddo River—Caddo Gap, Lenox, and DeGray—and three on the Little Missouri—Riggs Bluff, Matlock, and Narrows. Of these the DeGray and the Narrows are most suitable for flood control and power, but are of much less value than Blakely Mountain.

Core drilling by the power license applicant, the Arkansas Power & Light Company, at the Blakely Mountain site, show foundations suitable for a masonry dam 200 feet high to develop 76,000 kw at a cost of $13,000,000.

4. *Navigation:* By the past expenditure of $5,250,000 on projects for a six- to nine-foot channel for navigation, 350 miles of the main stem from the mouth of the Black to Camden, Arkansas, have been made navigable and snags have been removed for an additional 66 miles to Arkadelphia. About as much more mileage in the tributaries has been included. The annual cost of snagging and channel work amounts to about $80,000 and the annual maintenance of the six locks and dams aggregates about $185,000.

The tonnage carried on the river in 1931 consisted primarily of sand, gravel, and logs, with some cotton and machinery. It was mainly consigned to Monroe, Camden, and local communities. It amounted to 217,000 tons. No extension of navigation improvements on the river is recommended.

All Southwest Basins

Water Supply and Waste Disposal: Water supply is of vital importance to every individual in the Southwest Basins. Few public works investments pay greater dividends. In the same category and inseparably associated with public works supplies from surface sources comes sanitation. Of ever-increasing moment as population density grows, sewage and waste disposal must be included in any comprehensive water utilization program.

There are in the Southwest Basins more than 200 communities of which 60 percent use surface water and 40 percent use wells. Their total annual consumption is some 53 billion gallons per annum. Only 40 percent of the supplies are treated at present.

A striking example of reuse of water on a stream where congestion of population has outgrown the unregulated water supply available, occurs on the Grand-Neosho of southeastern Kansas and eastern Oklahoma. Here 50,000 people suffer periodically from water shortage as the river flow is depleted forming stagnant pools.

P.W.A. applications for water-supply improvements for 200 municipalities of the Southwest Basins exceed $15,000,000. Sewerage applications exceed $7,000,000.

A complete study of potential water supply and sanitation requirements, as far as can now be predicted, is recommended in order that the existing lack of information may not militate against the most beneficial use of water in the future.

Forestry: Nearly three-fifths of the Southeastern Basin is within the treeless region. The headwaters of the Arkansas River are in the forested ranges of the Rocky Mountains; there are narrow strips of timber along streams in the plains and prairie sections; most of the forests are in the eastern portion. These eastern forests are chiefly mixed hardwoods; with small areas of oak and pine with a limited representation of longleaf pine. The lower stretches of the main rivers are bordered by the southern lowland hardwoods with some scattered areas of cypress.

The upland forests are particularly important in checking erosion and retarding run-off. Their value in this regard has been greatly impaired by exploitation without reference to replacement, and by destruction of the ground cover by fire. The lumber industry has of late years been on a decline. Under adequate protection and systematic management the forests of the Basins should in the future contribute materially to the industrial development of regions where they occur, as well as render a service in recreation and conservation of wild life.

National Forests have been established in Arkansas, Oklahoma, and Louisiana comprising an aggregate gross area of more than 2,500,000 acres. Forests at the headwaters of the Arkansas River are embraced in the National Forest system and cover about 1,700,000 acres. These areas are of special value in protecting the slopes from excessive erosion, and in providing recreational facilities. They also form a nucleus about which a national forestry program can be built.

Commercial lumbering, which has been on the decline in Arkansas and Louisiana might advantageously adopt a timber crop rotation schedule inasmuch as many of these lands have no other value than for forestry. Wood-pulp production on a large scale is possible in the backwater areas of the Mississippi.

Soil Erosion: The most serious loss occurs from sheet erosion on the farms in central and southern Oklahoma and in northern Texas. Wind erosion has greatly impaired lands in the region centering about the panhandle of Oklahoma and in some other sections. Large areas have also reached the stage of gully erosion. Thus in Oklahoma alone about five million acres are unusuable for cultivation because of gully erosion. Forest and grass fires and overgrazing have been primarily responsible for serious erosion in wooded sections and on open ranges. The advancement of agriculture and grazing in upland and hilly sections of the Basins depends in part on the introduction of methods of tillage and land use which will check the erosion now under way.

In the evaluation of projects cognizance has been taken of possible erosion-control benefits.

Recreation: There are parts of the Southwest Basins, notably in Kansas, Oklahoma, and Texas, where parks and lake resorts are so scarce that people are obliged to travel long distances for recreation. In days of prosperity the wheat farmers of the region could make periodic pilgrimages to national parks, and forests, but during depressions the demand for local recreational facilities attached hitherto unrecognized value to a small body of water or a clump of trees.

The value of many reservoirs can be enhanced by retaining sufficient residual storage for recreation purposes without materially decreasing their value for water power.

As frontiers disappear and population density increases the social benefits of recreation must be recognized in national and State planning. The comprehensive plan for the development and use of water resources of the Southwest Basins includes the social as well as the economic considerations in a well-balanced program.

TABLE NO. 2.—*Classified summary of cost of projects of Southwest basins*

[Figures in thousands, 000 omitted]

Drainage area	Flood control	Power	Navigation	Irrigation	Water supply	Total
Red River:						
A	$3,820	$170	....	....	....	$3,990
B	19,560	22,362	$5,701	$10,000	....	57,623
	23,380	22,532	5,701	10,000	....	....
Arkansas River:						
A	13,244	13,290	....	10,000	$1,700	38,234
B	20,743	11,223	....	6,571	3,055	41,592
	33,987	24,513	....	16,571	4,755	....
White River:						
A	556	16,580	....	....	....	17,136
B	10,561	23,253	....	8,200	....	42,014
	11,117	39,833	....	8,200	....	....
Ouachita River	....	14,200	....	....	....	14,200
Total A projects	17,620	30,040	....	10,000	1,700	59,360
Total B projects	50,864	71,038	5,701	24,771	3,055	155,429
Total A and B projects	68,484	101,078	5,701	34,771	4,755	214,789

THE LOWER MISSISSIPPI REGION

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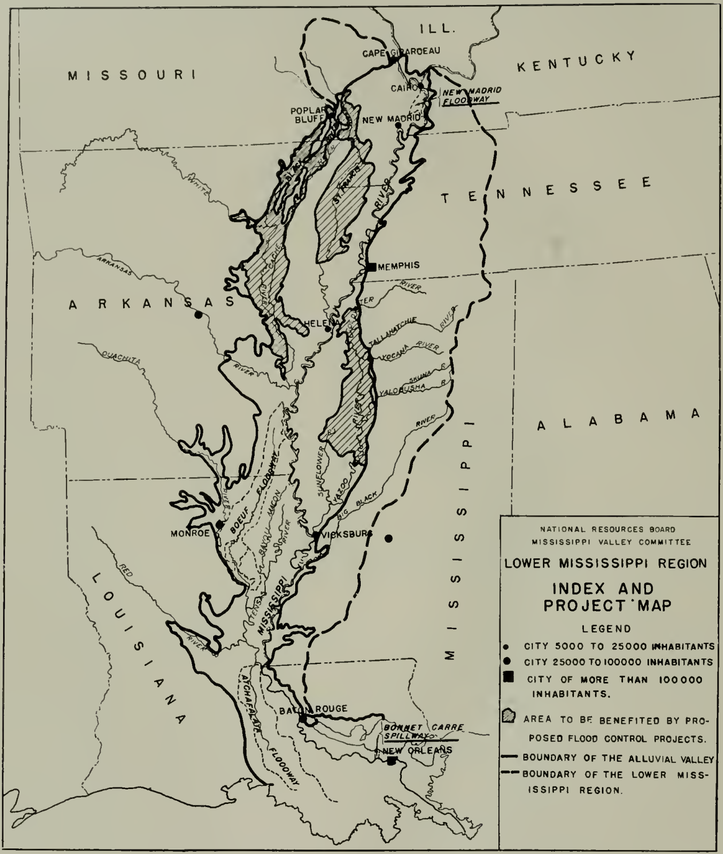


An Index to the Lower Mississippi Region and to the Projects There

THE LOWER MISSISSIPPI REGION

The Alluvial Valley and the Adjacent Uplands Drained by Minor Tributaries of the Mississippi

1. Social Conditions and Objectives

Basic Questions: The future of the alluvial valley of the Mississippi hinges on the flood problem, because, as in the past, economic development there will be restricted largely to the protected areas. Only half of the alluvial valley will be protected from all floods when the works now under construction or contemplated in accordance with the Adopted Plan for flood control are completed. Is it desirable and feasible to provide effective protection for more of it? Since the prime objective of all social planning should be the maintenance or attainment of a high standard of living, this question leads to others. Should the mode of life now dominant in the lower valley be extended? Can some improved system of life, conducive to human betterment, be established and maintained in additional areas that may be protected and developed? Can the rich natural resources of the valley be made to yield a more abundant living?

Just as the future of the alluvial valley hinges on the flood problem, so the future of much of the adjacent uplands turns on the problem of soil erosion, which has reached an advanced stage over large areas. How best may the denudation of the Uplands be checked, and how best may the lot of the farmers who occupy these eroded, submarginal lands be improved?

The Present Population: The population of the Lower Mississippi Region was approximately 3,905,000 in 1930. Of this number, 60 percent lived in the alluvial valley, or Delta, as it commonly is called, and 40 percent in the Uplands. The density, greater in general in the Delta than on the Uplands, ranges from fewer than 18 persons per square mile to more than 90. Much of the Delta is potentially capable of supporting a far larger population than it does now, while much of the Uplands is incapable of supporting properly its present population.

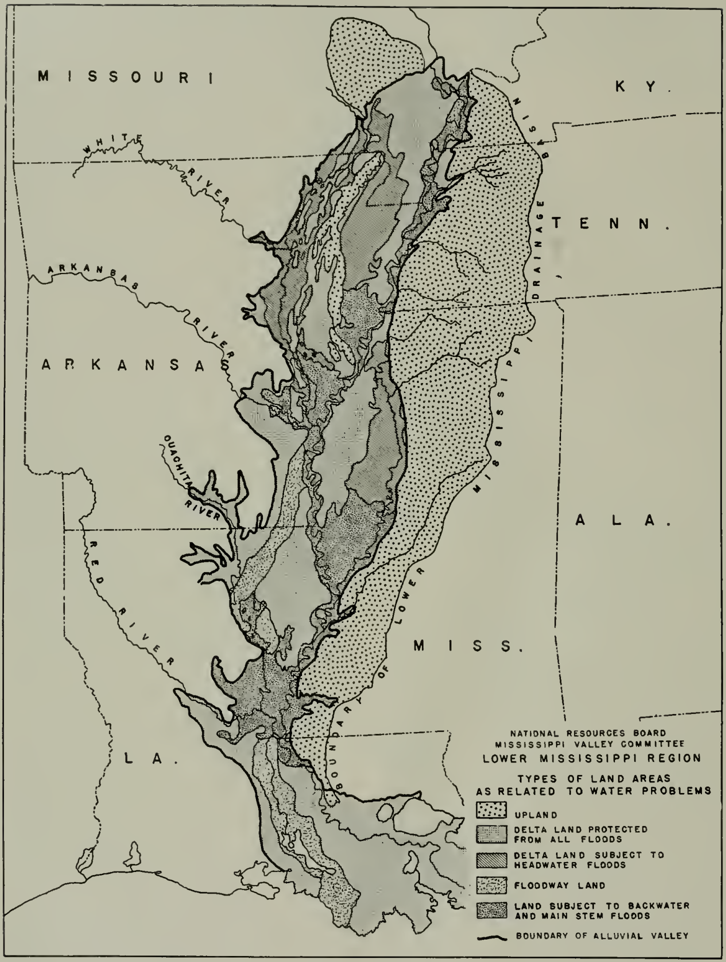
The negro population, in greater measure than the total population, is denser in the Delta than in adjoining areas. In the northern part of the Yazoo Basin, for example, the density of negroes exceed 85 per square mile, while in part of the Ozark Highlands it is less than 1 per square mile.

Most parts of the Delta have gained consistently in population during the last twenty years, and most parts of the Uplands have lost. In the Delta, the districts that have been most subject to floods are in general those that experienced most recent (belated) growth in population.

Dominance of Agriculture: In the Delta and the Uplands alike, about two-thirds of the total population is rural. In both sections, too, about half the total population depends *directly* on agriculture. Even the larger urban centers depend chiefly on commerce rather than industry, and with few exceptions the smaller cities and villages, distributed rather evenly throughout the region, are merely trading centers for the surrounding countryside. Though farming is everywhere the principal activity in the Delta, only half of its total land area is in farms. The proportion of all land in crops ranges from 10 percent or less in parts of the lower Red and Tensas basins to 60 percent or more in the northwestern part of the Yazoo Basin.

Types of Farming: In the Delta and the adjoining Uplands drained by minor tributaries of the Mississippi there are twelve areas, large and small, that in greater or less degree differ one from another in the type of farming practiced. It is noteworthy, however, that one-crop cotton farming characterizes the northern two-thirds of the Delta, and most of the Uplands. One-crop sugar farming is outstanding in the southernmost third of the Delta. At both the northern and southern borders of the Delta and in scattered parts of the Uplands, specialized grain, dairy, or truck farming provide some variety in agricultural produce.

Standard of Living: Lands of the Delta that are protected adequately from floods and that are drained properly are inherently capable of supporting a highly prosperous rural society. The fertile soils, the long growing season, the generous rainfall, the comparatively short distances to ports and to great markets together afford an exceptional basis for social development. The prevailing standard of living at present is evidenced by such facts as: (1) The gross income per acre from all farm products in 1929 was less than $10 over half or more of the Delta, although it ranged as high as $25 in restricted areas having maximum flood protection. (2) More than half the farms over most of the Delta, more than three-fifths of them over much of it, and more than nine-tenths over some of it, reported for 1929 an aggregate value for all products of less than $1,000.


MISSOURI
KY.
TENN.
ALA.
MISS.
ARKANSAS
LA.
WHITE RIVER
ARKANSAS RIVER
OUACHITA RIVER
RED RIVER
MISSISSIPPI DRAINAGE
BOUNDARY OF LOWER MISSISSIPPI DRAINAGE
NATIONAL RESOURCES BOARD
MISSISSIPPI VALLEY COMMITTEE
LOWER MISSISSIPPI REGION
TYPES OF LAND AREAS
AS RELATED TO WATER PROBLEMS
UPLAND
DELTA LAND PROTECTED FROM ALL FLOODS
DELTA LAND SUBJECT TO HEADWATER FLOODS
FLOODWAY LAND
LAND SUBJECT TO BACKWATER AND MAIN STEM FLOODS
BOUNDARY OF ALLUVIAL VALLEY

Map showing the different types of land areas in the Lower Mississippi Region.

Forty to 70 percent of them in a relatively large area at the south and 20 to 40 percent and more in a comparable area at the north reported the total value of all products at less than $600. (3) In many counties the percentage of farms reporting habitations lighted by electricity in 1930 was less than 1, and in only four was it 5 or more. (4) More than 20 percent of all persons over ten years of age are illiterate in a belt of variable width extending from the Gulf Coast to southwestern Tennessee. In some localities, the percentage exceeds 20 and even 30. For the entire population of the country it is 4.3, and for the total rural population, 6. (5) As in earlier decades, tenancy increased more or less almost everywhere in the Delta from 1920 to 1930, locally by more than 12 percent. About eight-tenths of all farm operators there are now tenants.

The foregoing statements regarding the Delta are applicable in general to the Uplands, although on the less fertile and more erosive soils of the latter the conditions of rural life are even more meager. In 1930, the average value of all products per cotton-farm operator was about $300 less in representative Upland counties than in representative Delta counties. Tenancy ranges from 50 to 90 percent in the eastern uplands, but does not exceed 30 percent in the Ozark portions of the St. Francis Basin. During the decade 1920–1930 it increased in most parts of the Uplands and in several parts by as much as 14 percent.

The tenant system is a concomitant of the low standard of living prevailing in most of the Delta and much of the Uplands. As a ladder to ownership of land it has proved an utter failure. With few exceptions, the tenants, especially those on the cotton plantations, never get out of debt.[1] An average cropper whose share of a cotton crop is worth, say, $300 to $500, has pitifully little to spend for food, clothing, furnishings, medical care, and other needs. Of necessity he operates largely on credit, obtained from or through his landlord at a high rate of interest. In many cases he is discouraged or even prevented from growing food crops for his family on part of the land allotted to him.[2] He lives in an unpainted, comfortless cabin of two rooms, furnished with the bare necessities of existence (beds, a few chairs, a table, a stove), and devoid of sanitary facilities. If he leaves the plantation because of the operation of the cotton-reduction plan or for some other reason, he probably must go on the relief rolls, since there is little or no chance for him to secure employment in industry.

A New Social Order: Stabilization of the old social order in most of the region will accomplish little toward human betterment. The pernicious tenant system should be abolished as soon as practicable through readjustment in land utilization and ownership. Meanwhile, the degrading mode of life which it tends powerfully to breed and perpetuate should not be permitted to spread. To this end, additional flood control for partially developed or undeveloped portions of the Delta should be undertaken only in connection with and as part of a program of land development, occupation, use, and ownership that will insure a notably higher standard of living than now prevails there. Such a program can be carried out in the relatively near future only by the Federal Government, or under its leadership and with its generous support. The magnitude of the undertaking, the technical and social difficulties involved, and the heavy expenditures required preclude successful action by land owners, local communities, or even the states within whose borders these lands are located. Suggestions for a realistic approach to the problem of formulating such a program are made in later pages.

II. Types of Land Areas as Related to Water Problems

The Uplands

Erosion the Chief Problem: The most critical and wide-spread water problem in the uplands of the Lower Mississippi Region, and the most critical and wide-spread land problem as well, is that of soil erosion. It is most acute in the upper Yazoo Basin, though serious also in the uplands of southwestern Mississippi, in westernmost Tennessee and Kentucky, and locally to the west of the Mississippi on Crowley's Ridge and in the upper St. Francis Basin. The following discussion is restricted to the upper Yazoo Basin.

Principal Causes of Erosion: The rainfall of the upper Yazoo Basin is heavy (about 50 inches annually) and the soils, mostly silt loams or loess, are washed easily from slopes of even moderate steepness that are not effec-

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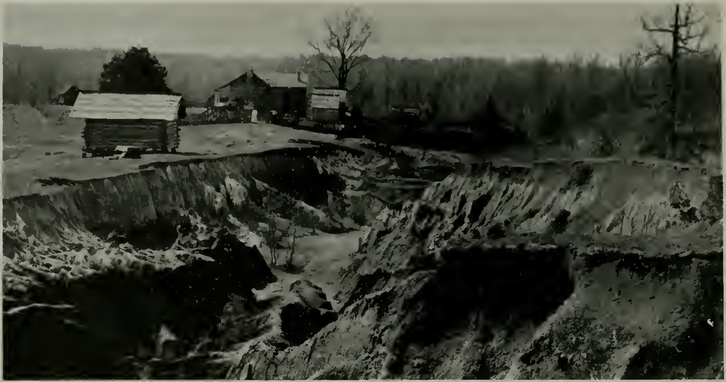
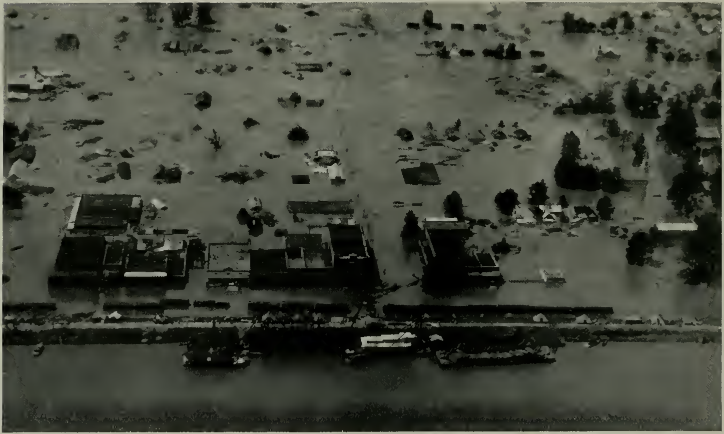
[1] Forty to 60 percent of the tenants are "croppers", and the remainder either "share-renters" or "cash tenants." Croppers furnish only their own labor and that of their dependents, and receive half the crop from their "cuts" of land; share-renters supply labor, implements, and work animals, and get two-thirds of the crop; cash renters provide labor, implements, and stock, pay a cash rent, and obtain the entire crop.

[2] In parts of the Yazoo Basin the average value of farm products used by the operator's family was less than $50 in 1929; over half or more of the Delta, it was less than $100. On the other hand, more than 90 percent of all farm products was sold or traded in 1929 throughout most of the Delta.



U. S. F S. Photo.



Weather Bureau Photo

Above—an advanced stage of gullying in the silt-loam section of the Yazoo uplands. Incipient gullying is widespread in cultivated fields in this section. Below—Arkansas City, Arkansas flooded by Mississippi River waters in 1927. Even though the Mississippi is confined in the future there are Delta towns that will be under water unless protection is afforded against the floods of minor tributaries.

tively protected by vegetation. Once begun, gullies grow rapidly and chasms 30 to 50 or more feet deep are common. Deforestation, the practice of burning pastures annually, the use of most cultivated land year after year for cotton and corn, and the wide-spread use of careless methods of tillage are basic factors in the deterioration of the land. The traditional objective of securing the largest possible yield of a single money crop discourages crop rotation and the planting of forage crops, while it encourages the cultivation of very steep slopes after those less steep have been exhausted. Tenant operators have little or no inclination to spare the soil that others own. Most landlords permit or encourage procedures that rob the land, and look only to maximum yields while the soil lasts.

Losses from Erosion: The prevailing system of farming results not only in impoverishment of the land and its later abandonment, but also in economic and social retrogression that leads to financial and cultural poverty. The aggregate differences between the present values per acre of uneroded lands of various classes in the Yazoo Uplands, assuming that those lands were all put to their best use, and those of corresponding lands that have been injured in varying degree by erosion amount to approximately $16,000,000. This figure will be increased by some $3,400,000 by 1945 if the land is not given proper care. Impressive though these figures are, they cover only one of the types of damage, direct and indirect, that the area has experienced from erosion, and they take no account, of course, of damages in the Yazoo lowland inflicted by silt-laden flood waters from the denuded hills.

Principles of Action: Forestry and conservative grazing represent the best uses for most of the hill lands of the basin, since without a protective cover of trees or of sod, denudation will continue actively to its final stage. Commercial forestry affords private interests no prospect of early profit, and livestock farming on a significant scale is as yet in the stage of experimentation. Public participation in the physical and economic rehabilitation of the area is essential. The Federal Government should continue the purchase of eroded lands there with a view to planting forests, controlling grazing, and checking gullying, and should give appropriate assistance to owners of uneroded lands in order to control denudation.

Delta Lands Protected From All Floods

In the western part of the Yazoo Basin, the eastern part of the St. Francis Basin, the lower Delta, and parts of the Atchafalaya, Boeuf, and Tensas basins, the flood hazard will be reduced to a minimum by the Adopted Plan, and in those areas the chief problems of water relate to drainage, domestic supplies, and navigation.

Drainage Problems: More than four-fifths of the protected lands is in drainage enterprises constructed between 1905 and 1925, and these lands are the most prosperous in the Delta. In 1930 they had the larger percentages of land, both in farms and in crops, and the higher gross incomes per farm operator.

In their native condition these lands were covered with valuable timber, most of which has been removed. The growth remaining on cutover lands has slight commercial value, although it is useful to settlers as domestic fuel. To change such land to a condition suitable for profitable agriculture and for satisfactory habitation would necessitate clearing the land of standing timber and stumps, providing farm drainage and main ditch outlets, building fences and houses, and constructing highways. Acquisition of land and reclamation work would cost, under present conditions, approximately $100 per acre.

Many of the drainage districts are in default on payments due on their indebtedness, partly because of low prices for cotton and partly because they have not been settled completely. Approximately 1,500,000 acres in drainage enterprises in protected parts of the Delta were not in farms in 1930, and they included at least 650,000 acres available for immediate settlement. The Reconstruction Finance Corporation is empowered to aid districts in acute financial distress by means of refunding operations, but at the present rate of settlement five years or more will elapse before all the vacant lands in the protected districts are occupied. The drainage of more land meanwhile would provide injurious competition to areas suffering from lack of settlers and eminently suited to agricultural occupation.

Water-supply Problems: The protected parts of the Delta have a clean and dependable supply of water either from the Mississippi River or from the artesian reservoirs that underly the entire region at depths of from 300 to 2,000 feet. Because of the ease with which the upper ground waters are polluted, the presence of obnoxious vegetal matter in the alluvium, and the low flow of most of the tributary streams in the dry season, surficial supplies of water are not satisfactory. In four cities of the lower Delta of Louisiana and especially in New Orleans, where the water table is very near the surface, the disposal of storm run-off constitutes a problem the magnitude of which has taxed local financial resources. Farther north, lack of suitable facilities for sewage disposal has created difficult problems of sanitation in at least ten towns and the neighboring rural areas.

Navigation: Although the protected lands support the older communities and denser populations of the Delta, the improved waterways that traverse them are not serving as important highways of trade. The Federal Government has spent to 1933 approximately $1,010,000 on the improvement of the Big Sunflower and Tensas Rivers, Bayou Macon, and Bayou Steele. The annual maintenance charge on these streams amounts to about $13,000 and the interest charge on the construction cost, at 4 percent, to $21,600. The average annual cost to the Government per ton-mile for the traffic that moved during the period 1928–1932 was 6.0 cents on the Big Sunflower River, and 1.7 mills on Tensas River and Bayou Macon. Almost no traffic moved on Bayou Steele, which was recommended for abandonment.

Principles of Action: In the light of the investigations, the results of which have been summarized briefly in the foregoing paragraphs, the following Federal policies seem desirable.

1. Until the unoccupied land in existing drainage districts in the protected parts of the Delta is settled in large part, the construction of new drainage works in the Delta or of flood-control works likely to induce new drainage enterprises there should not be undertaken.

2. Federal aid is justified in financing the construction of water-supply and sewage-disposal works in urban areas in which the pollution of water supplies is a definite menace to health.

3. Maintenance of uneconomic minor waterways in this part of the Delta should be discontinued.

Delta Lands Subject to Headwater Floods

Although about two-thirds of the Delta is to be protected from *Mississippi River floods* under the Adopted Plan, about one-fifth of the section will still be subject to serious flooding from the minor tributaries. In addition, there are large areas within which the successful tillage of the land is precluded by the high-water table. The control of floods originating in the nearby uplands is, indeed, the outstanding water problem in the lower Mississippi Basin. A satisfactory solution of the problem should greatly improve local conditions, both economic and social, and should yield substantial benefits to the nation.

Flood Protection and Drainage: On a minimum basis, approximately 7,000 square miles of fertile alluvial land in the St. Francis, White, Ouachita, and Yazoo basins are flooded at times, causing an average annual tangible damage estimated conservatively at $4,280,000. These areas are characterized by scattered clearings on the higher tracts along roads which traverse wide expanses of cut-over forest. Stumps still stand in many fields, and the cabins are new. As compared with the neighboring lands protected from all floods, these lands are much less prosperous and much less developed. Two-thirds or more of them are in drainage enterprises whose levees, constructed independently of one another, have intensified the flood problems of districts downstream, whose financial resources in most cases are insufficient to build and maintain adequate protection works, and whose present condition is, in general, one of insolvency. Lack of coordination of the weak levees that do exist has caused bitter friction between neighboring districts, and has necessitated heavy expenditures by the Federal Government for reconstruction following high floods. Reservoirs would provide far more dependable protection and would reduce the flow from many streams into the main stem of the Mississippi. It would require, however, a degree of cooperative effort on the part of local interests that has been lacking. The distress of the districts is due (1) to the high costs of construction necessitated by the flood hazard; (2) to improper design, lack of correlation, and neglect of maintenance; (3) to the flood damages suffered by the farmers paying assessments; (4) to the low prices of cotton, and partly (5) to the reluctance of new settlers to buy land subject to flooding. Lumber companies and drainage districts alike have fostered many settlement schemes, but with little or no success. Large scale, and, in many cases, speculative, agricultural enterprises have been numerous and one-crop cotton culture has been dominant.

Effective flood protection would benefit the present population not only by eliminating flood losses, but also by strengthening the financial condition of the drainage districts, in many of which 80 percent of the assessments for 1933 are unpaid. Moreover, if the settlement of the unoccupied land, when protected, were so regulated as to promote land ownership and a diversified and suitable type of farming, the indirect benefits would be felt by new settlers, by their neighbors, and by the country at large. On the other hand, uncontrolled settlement would result merely in a perpetuation of existing social conditions.

Water Supply: In those areas, subject to headwater floods, which have experienced relatively slight development, in part because of the flood hazard, the problem of water supply and sewage disposal is a pressing one for small communities. Towns having populations of 1,000, more or less, flooded occasionally, located in backward agricultural areas, none too prosperous themselves, and facing an uncertain future, are lacking in water and sewage systems. They suffer in common with nearby farmers from water pollution during periods of high water.

Navigation: The stage of cultural development in the areas under consideration makes it most unfair to judge their minor waterways solely on the basis of present traffic. So far, however, as the improved waterways previously mentioned that traverse well-developed areas afford a basis for prediction, no substantial gains in traffic may be anticipated. The total cost of improving the St. Francis, White, Black, Current, Tallahatchie, Coldwater, and Yazoo rivers as of 1933 amounted to $4,848,000, and the annual maintenance charges were approximately $148,200. The average annual Governmental expenditure per ton-mile for tonnage moved during the period 1928–1932 was 8.3 cents on the St. Francis River, 3.1 cents on the White River, 2.2 cents on the Black River, 3.9 cents on the Current River. 40.4 cents on the Coldwater and Tallahatchie rivers, and 1.5 cents on the Yazoo River above its mouth.

Principles of Action: 1. The protection of areas subject to headwater floods originating on the minor tributaries of the lower Mississippi is highly desirable as a means (a) of eliminating recurrent crop damages, (b) of improving the financial condition of existing agricultural enterprises, and especially (c) of raising the standard of living of the present and prospective populations. Protection should be attained by building reservoirs where practicable both from an engineering and an economic standpoint, even though they cost more than levees or floodways. Although in some areas of small size protection by levees alone may be the cheapest method from a local point of view, nevertheless reservoirs may afford cheapest protection from the standpoint of the given drainage area as a whole. From an economic point of view alone, protection is feasible immediately for lands in connection with which the average annual tangible flood damages exceed the annual cost of the requisite works. From a social viewpoint, however, such flood-control work should be contingent on the provision of technical and social facilities adequate to develop a relatively high standard of living. Under no circumstances should the Federal Government aid in the protection of these lands without having control of the prospective "unearned increment" in land values and of the type of agriculture to be practiced on the lands. The nature and extent of the benefits to be anticipated from a controlled program of settlement would seem to justify the assumption by the Federal Government of the cost of directing such a program and of one-third, at least, of the cost of constructing the flood-control works. The costs not assumed by the Federal Government should be borne by the beneficiaries and should not exceed an amount which could be paid off in annual installments over a period of approximately twenty years. In general, protection should be developed first for areas that already are in drainage enterprises.

2. Federal aid is warranted in financing water-supply and sewage-disposal works for small towns around which pollution is frequent, especially in areas that probably will experience growth in population as a consequence of flood protection.

3. An intensive study should be made of the increase, if any, in waterway traffic that probably would result from further development of the adjacent lands. In the light of the findings, the feasibility or nonfeasibility of continued maintenance of the improved waterways should be determined.

Floodway Lands

Under the Adopted Plan, approximately 4,000 square miles of land in the Delta constitute floodways designed to carry excess waters from the leveed channel of the Mississippi on an estimated average of once in thirteen years.[3] The New Madrid and Bonnet Carre floodways are complete and the Atchafalaya floodway is under way, but construction has not begun on the Boeuf floodway. Even if levees and floodways are competent to prevent lower Mississippi River floods, the works under construction or projected are causing other problems that challenge attention.

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[3] This estimate is for land above the limits of backwater flooding.

The Problem of Flood Damages: Chief among the problems provoked by the flood-control measures taken to date is that of the occupation of the lands within the floodways. With respect to this problem, the Federal Government might take any one of the following positions.

1. *The Government Might Take no Action Other Than to Complete the Guide Levees as planned:* This is the present policy in the Atchafalaya and Boeuf basins. It will not be known until after the first flood waters have moved down those floodways whether or not the Government will have to pay for damages. It is estimated that if the courts should hold an obligation to do so exists, the cost to the United States resulting from the diversion may amount to many millions of dollars for a single big flood. Pending a great flood necessitating use of the floodways and the subsequent judicial opinion as to liability, roads are being built in the areas involved, settlers are arriving in small numbers each year, and the population on the ground is hampered by the reluctance of credit agencies to help finance operations where so much uncertainty attaches to economic development. In the Boeuf Basin there has been agitation for building the fuse plug levees up to standard grade and section and thus maintaining them until the guide levees are completed. *Even if not obliged to pay damages, the Government doubtless would have to make heavy expenditures after every high flood for the relief of distress among the people of the floodways.*

2. *Payment for Flowage Rights Might be Made:* This was done in the case of the New Madrid and Bonnet Carre floodways, which occupy land not submerged in recent years, and in which pre-existing protection was being reduced or eliminated by the United States. A similar procedure in the Atchafalaya and Boeuf floodways does not seem to be the best solution because (1) the total cost of purchasing flowage rights would be extremely high, probably nearly as much as the present value of the lands, and (2) such purchase would not obviate the need of extending relief to sufferers from floods.

3. *The Government Might Construct Fixed Spillways in the Mississippi Levees for the Accommodation of Waters Entering the Floodways. The effect of these would be to control definitely the position of the overflow and minimize its extent and duration, thus perhaps reducing the cost of flowage rights sufficiently to make their acquisition practicable.* Possibly cooperative agreements might be made with the States and local interests affected, under which the improved conditions established in the floodways by means of such spillways would be held to offset the minimized damages that would be inflicted when waters from the river entered the floodways. This may prove to be the most rational plan.

4. *The Government Might Try to Promote Commercial Forestry in the Area, and to Secure Zoning of the Land by the Respective States:* In view of the economic risk and the relatively long investment involved in the production of bottomland timber, and in view further of the strong opposition to the floodway features of the Adopted Plan in the states concerned, this procedure appears to be inexpedient. The promising chance of collecting damages after the next great flood, the high productivity of most of the soil, and the relatively infrequent occurrence of major floods, restrain landowners from abandoning or curtailing their agricultural operations.

5. *The floodway land might be purchased by the Government* and might be used to grow timber or be leased to farm operators required to maintain permanent residences outside of the floodways.

Drainage Outlets: Even though some satisfactory disposition of the lands within the floodways be made, agricultural occupation of the adjacent protected areas will still be hampered by the "cutting off" of natural drainage outlets through the building of guide levees. The need of Federal aid in providing new drainage channels behind the guide levees in order to prevent flooding already has been recognized in the Atchafalaya Basin. A similar need will become apparent in the case of the Boeuf Basin, if and when guide levees are constructed there.

Navigation: The major floods that probably will occur from time to time in the floodways doubtless will prevent any notable development of the economic life of the areas. The prospects therefore are dim for an increase in traffic on the local waterways. As of 1933, the Boeuf River improvement has cost a total of $131,000 and required approximately $2,500 a year for maintenance. The average annual cost to the Government of tonnage moved during the period 1928–1932 was 7 mills per ton-mile.

Principles of Action: 1. If the Federal Government should purchase the land in the floodways that is above the limits of backwater flooding, careful consideration should be given to all the equities, both private and public. The land acquired should be classified according to its best use, in view of its character and situation, and should be devoted to national forests, leased for suitable private use under controlled conditions or otherwise employed, as its classification may dictate.

2. The Federal Government should stand ready to share the cost of alteration in drainage outlets necessitated by the construction of guide levees under the Adopted Plan.

3. The maintenance of the uneconomical improvements for navigation within the floodway areas should be discontinued and no further improvements there should be undertaken.

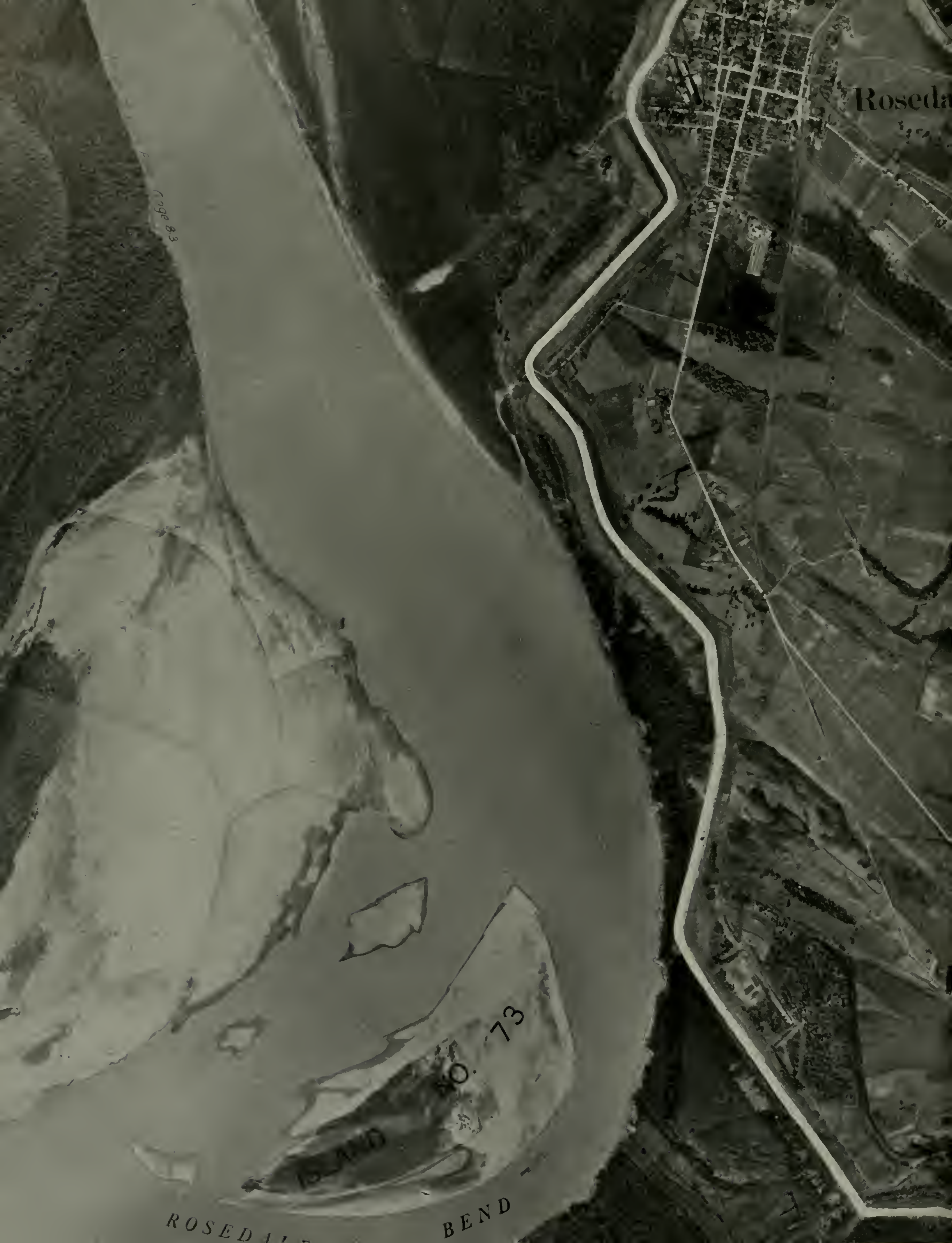
Delta Lands Subject to Backwater and Main Stem Floods

Approximately one-quarter of the Delta is subject to flooding from the main stem of the Mississippi River or its backwaters. The lands thus flooded are populated very sparsely and, for the most part, can be protected only at great cost. They constitute a unit of questionable importance in any plan of flood control and land development. Along their borders flows the Mississippi. The existing Federal policy with respect to both lands and waterway has tended and will tend increasingly to promote unwise expenditures for the use and control of water.

Flood Protection: Some parts of the flood plain of the main stem and the backwater areas at the mouths of the St. Francis, White, Arkansas, Yazoo, and Red rivers are flooded to various depths annually, and other parts as infrequently as once in 15 years. A few scattered parts have been protected by levees, but most land of this type either is unoccupied or is settled in small tracts by speculators and homesteaders who risk frequent loss of crops and who are prepared to retire to their housetops or to evacuate their lands during periods of high water. At least four-fifths of the backwater areas is timber land, mostly cutover land, owned by lumber companies. Protection of some reaches along the main stem would raise the flow line, and therefore would require raising the levee grade on the opposite bank. On other reaches no change in flow line would occur. The value of the backwater areas as natural reservoirs in time of peak flow is questionable; the floodways were designed to accommodate the overflow of superfloods, and it was assumed that floods of less height would leave an adequate freeboard. Although independent protection of very little of the backwater areas is feasible at present—assuming that feasibility is determined by balancing costs against the damages that would be averted—it seems certain that continued settlement eventually will develop so much property exposed to damage that local interests will marshal impressive evidence of the need for protection. The Flood Control Act of 1928 set aside funds to defray two-thirds of the cost of building control works in the backwater areas. However, flood control in those areas may be regarded properly as a phase of reclamation. Such reclamation if prosecuted in the near future, would offer active competition to settlement and development in areas already protected and drained, or in areas preferred by reason of the lower cost of protection and the larger populations involved.

Utilization of Unprotected Lands: A definite Federal policy designed to discourage agricultural expansion in these backwater and main stem areas should, if practicable, promote some other use of the land. Commercial forestry, which appears to be the most promising alternative use, is untried as yet in the Delta. Specific information is lacking concerning the productivity of mixed hardwoods in the backwater areas and of cottonwoods along the main stem, and concerning the costs involved in their management. The rapid growth of certain hardwoods and the possible use of cottonwood for paper pulp apparently would justify experimentation in Delta forestry by a Federal agency. Such experimentation might demonstrate the feasibility of action by private interests and (or) necessity of government participation in a forestry program. The first areas chosen should be used also as game refuges.

Navigation: Just as there is some danger that the flooded areas adjacent to the main stem may be used to induce uneconomical Federal expenditures in the relatively near future, so, too, the main stem itself may receive expenditures for navigation out of proportion to the actual benefits, direct and indirect, to be derived from them. The total cost of improving the Mississippi River for navigation in the section between New Orleans and Cairo may be estimated conservatively at $190,000,000. This includes $110,000,000 spent, or to be spent, under the Adopted Plan. The average annual maintenance costs are at least $2,700,000. During the period 1928–1932 the average annual traffic, exclusive of material used in government work and the coastwise and foreign petroleum traffic below Baton



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Rouge, was about 1,681,000,000 ton-miles. If this volume of annual traffic continues unchanged the total Government subsidy provided shippers by water would be, at the time of completion of the work now under construction, about 6 mills per ton-mile. Allowing for the meandered course of the river, involving distances by water that are some 50 percent more than those by rail, the actual public expenditures, when reduced to a basis comparable to expenditures for rail haulage, would be approximately 9 mills per ton-mile. More than two-thirds of the traffic moved in the section below Vicksburg. Grain, cotton, and sugar were prominent items in through movements. With the exception of short hauls of sand and gravel, the use of the stream for local commerce was inconsequential. The Mississippi is a traffic artery of national, rather than local, significance. Its value as a unit in the national transportation system is generally thought to be great, but the matter seems to merit more thorough and comprehensive consideration than it previously has received.

In an effort in part to encourage greater use of the river, Congress created the Inland Waterways Corporation in 1924. At that time it was the opinion of the House Committee reporting favorably on the measure that:

> "If the Government, after making these rivers navigable, cannot profitably operate a transportation system on them, then it is hopeless to expect private capital to do so, and Congress should no longer appropriate money from the Public Treasury for a useless purpose. Therefore the committee was of the opinion that this bill should pass in order that this pioneering demonstration might be conducted by the Secretary of War until such time as its success or failure may be made apparent." (68th Congress, 1st, H.R., 375.)

Since 1926, traffic carried on the lower river has declined slightly. The Corporation appears not to have shown an appreciable net income from traffic operation, notwithstanding its exemption from taxes and from various administrative expenses. It has arranged many joint rates, has secured an increase in the minimum width of channel maintained, and has financed or helped to finance the construction of various municipal terminals.

Principles of Action: 1. The Federal Government should not participate in further protection of areas now subject to backwater and main stem floods until feasible reclamation projects in other parts of the Delta have been carried out, except that it should participate to the extent of the cost of administering a settlement program and of at least one-third of the construction cost of protection works in areas in which the average annual damages from floods now exceed the prospective annual costs of complete protection and in which drainage and some flood protection already have been developed.

2. Experiments in the care and utilization of the forests of the backwater and main stem areas should be undertaken as soon as practicable by the Forest Service in order to discover the feasibility or nonfeasibility of commercial culture there, and in order to frame a program of public-forest development in these areas in the event private enterprise will not be able to make profitable use of the land.

3. A detailed study should be made of the costs of, and the savings, if any, accruing from the improvement of the lower Mississippi River for purposes of navigation, with a view to determining whether or not the savings to the shippers warrant the payment by them of any charge for use of the waterway. Such a study might well involve a consideration as to whether or not there are good reasons for the continued existence of the Inland Waterways Corporation, in view of the spirit of the Act of 1924 by which it was established.

III. Control of the Mississippi Floods

Development of the Levee System: The alluvial valley extending from Cape Girardeau, Mo., to the mouth of the Mississippi River, contains some 40,000 square miles of flat land, which in its primeval condition was subject to submergence during high floods and was mostly covered with heavy timber. To ward off Mississippi flood water an extensive levee system was slowly developed. The history of this system affords a pertinent example of the gradual evolution of a great community social enterprise, of the growth in knowledge and steady enlargement of ideas resulting from the slow cumulation of gradually expanding experiences, and of the lessons that may be learned from a careful study of history.

Levees were begun along the river in front of New Orleans in 1717. During the next hundred years they were gradually extended upstream to the Arkansas. Under the French law it was the duty of every landholder having frontage on the river to build the levees necessary on his land to restrain flood waters from escaping from the river. This is still the basis of the law in Louisiana, under which the state has the right to take all land necessary to be occupied by levees.

The Mississippi River near the mouth of the Arkansas River. This view, showing meandered course, eroding bank, and shifting bar, is typical of many reaches of the lower river. Left, is a characteristic backwater area with heavy forest-cover and almost no signs of human occupation. Behind the levee, right, are cultivated fields of prosperous plantations which enjoy maximum protection (Photograph from Army Corps of Engineers).

By the Swamp Land Acts of 1849 and 1850 the United States gave to each state all the publicly owned overflowed land within its borders, in order to enable it "to construct the necessary levees and drains to reclaim the swamp and overflowed lands therein." Under this stimulus the levees were gradually extended until, by the end of the last century, they were practically continuous to the upper end of the alluvial valley, except where it was necessary to leave gaps to permit tributaries to join the main river.

When floodwaters from the Red, Arkansas, White, St. Francis, Mississippi, Ohio, and smaller tributaries entered the alluvial valley in a state of nature, they spread over the whole valley. The water that escaped over the south bank of the Red or from the Mississippi below the mouth of the Red finally reached the Gulf of Mexico through various bayous and lakes without ever returning to the Mississippi channel. The result was that the capacity of the Channel below the mouth of Red River was much less than it was farther upstream, and to this day the Mississippi Channel has a much greater capacity between the mouths of the Ohio and the Arkansas than it has below the mouth of Red River.

It early became evident that careful coordination and planning of the levees system was necessary, and to this end Congress created in 1879 the Mississippi River Commission, charged with investigating the various proposed methods for controlling the river and with preparing plans and estimates to fix it permanently, protect its banks, and facilitate its use.

Channel Stabilization: Like many other rivers the Mississippi has the unfortunate habit of eating into its banks here and there along its course and thus slowly changes the location of its bed. When caving banks threaten to engulf exceptionally valuable property, especially in the vicinity of towns, it is usual to protect the crumbling banks from further attack by constructing some sort of bank revetment. Such revetment is very expensive, sometimes costing several hundred thousand dollars per mile, and so far no perfect form of permanent revetment has been devised. The average life of the revetment constructed in the past has been estimated as 20 years. To avoid the expense of installing bank revetment, the usual remedy, when a caving bank threatens to undermine and destroy an adjacent levee, is to build a new piece of levee, called a set-back levee, sufficiently distant from the river as to be safe from further attack for a number of years, generally 20 or more.

Higher and Higher Levees.—After much discussion the Mississippi River Commission in 1883 established a tentative grade line for the top of the levees all the way from Cairo to the mouth of the river. As the levees were extended and raised it became evident that the grade was not high enough to confine the higher floods, so in 1898 the Commission established a new grade line averaging about five feet higher than the 1883 line. The levee system had scarcely been raised to this line when other floods, culminating in those of 1912 and 1913, showed the inadequacy of this line, and a third one was established in 1914 several feet higher than the 1898 grade. In establishing the 1914 grade, account was taken of height that would have been attained by the greatest previous flood and the grade line was put three feet higher so as to have this margin of safety. This margin was intended to cover accidental variations and future uncertainties. To that time every great flood had overtopped and washed away the levees in many places, flooding large areas and causing great loss, so that there had been no actual great flood fully confined to serve as an accurate standard of comparison.

Limitations of the Levee System.—The levee system had been brought almost everywhere to the standard 1914 grade line when the greatest reliably recorded Mississippi flood occurred in 1927. The levees were again broken in many places and the greater part of the whole valley was flooded. This led to by far the most thorough study ever made of maximum expected Mississippi floods and their control. It was found that the levees would have needed to be 5 to 10 feet higher than the 1914 established grade to have held the 1927 flood.

Congress adopted in May 1928, a new plan for the control of the Mississippi floods, known as the Jadwin plan or the Adopted Plan, utilizing floodways in addition to still higher levees for controlling the flow.

Features of the Adopted Plan: In addition to higher and stronger levees on both banks of the Mississippi River, the Adopted Plan provides for certain floodways running parallel to the river, through which a part of unusually high flood waters will flow. Only when the flood is so great that not all of the water can be carried safely between the levees along the main river channel, and there is consequently grave danger that the levees will be overtopped and broken, will the floodways come into use.

The three chief floodways are the Bird's Point-New Madrid floodway running from Cairo, Illinois, to New Madrid, Mo.; the Boeuf floodway running from the mouth of the Arkansas River to the mouth of the Red; and the Atchafalaya floodway running from the mouth of the Red to the Gulf of Mexico. At the upper end of each floodway a levee below standard grade separates the floodway from the main river channel. Following each flood involving floodway use the low levees at their entrance will be restored. Because the life of these low-entrance levees is temporary and uncertain, they are called "fuse plug" levees.

On the east side of the Mississippi River, the main levee is continuous from high ground near Baton Rouge to the Gulf of Mexico, and from high ground just below Memphis to the mouth of the Yazoo River just above Vicksburg. Since the Yazoo River is the natural outlet for all the run-off from the Yazoo Basin, it is necessary to leave this opening in the Mississippi's levee through which the Yazoo can discharge its flow into the Mississippi River. But as a result of the existence of this opening, when the Mississippi is in high flood, say 10 feet above the level of the ground along its banks, its water flows through the gap in the levee and up the Yazoo River, overflowing the low land along its low banks for many miles. Such an overflowed area is called a backwater area; one exists at the mouth of every tributary entering the Mississippi along its leveed course. The higher the Mississippi levees, and the higher the floods confined by them, the farther the water flows up the tributaries, and the greater the backwater areas become.

On the west side of the Mississippi, the levee is continuous along its banks from near Cape Girardeau, Mo., to the Gulf of Mexico excepting at the mouths of tributaries as follows: St. John's Bayou at New Madrid; the St. Francis above Helena; the Arkansas and White; and the Red. Adjacent to each of these openings are, of course, extensive backwater areas.

Existing Degree of Flood Protection: Although adopted as recently as 1928, the execution of the Adopted Plan is nearing completion at a cost of over $300,000,000, which covers both channel stabilization and control of Mississippi floods.

A recapitulation of the Adopted Plan's expected results shows that one-third of the whole alluvial valley will be consigned to frequent future flooding; less than two-thirds will be completely protected from Mississippi floods, but less than one-third is in a highly developed and productive agricultural state; more than one-third will be to a large degree uncleared, undrained, and unprotected from floods from tributary streams, conditions which may be ameliorated in the future through sufficiently large expenditures.

Ever since the plan was adopted it has been urged that the freeboard of one foot above the estimated high-water line for maximum probable flood provides too small a factor of safety. When the river flows around a bend, the water level at the outer bank is considerably higher than at the inner bank, the difference sometimes amounting to one foot. A strong cross wind can change the relative water levels on the two sides of a river by an appreciable amount, and wave action also carries the water up the levee slope a considerable distance. Every time that the river changes its channel either by making a cutoff, forming an island, or other means the water-surface levels are disturbed and changed. For many years it has been customary to contemplate a freeboard of three feet above the highest previous flood. The Adopted Plan has about a three-foot freeboard above the 1927 flood, and the same amount is now asked for the maximum probable flood. Undoubtedly in the future the attempt will be made to secure even greater freeboard than that now afforded.

Cost of Increased Freeboard: Additional freeboard can be obtained either by raising the levees to a greater height, or by using reservoirs to lower the flood peaks. The levee system is about 1,825 miles long and the average height is about 21 feet. To raise the levees one foot will require 40,000 cubic yards of earth per mile or over 70,000,000 cubic yards for the whole system. At 50 cents per cubic yard the total cost would be about $35,000,000. If the same result is to be obtained by constructing reservoirs, the same reservoirs will also be of great value for local flood protection, for assisting land reclamation, for producing water power, and for low-water control. The most favorable system of reservoirs for combined purpose use has not yet been worked out, so it is impossible to state what the total expense for obtaining an additional foot of freeboard by this method will be.

Reservoirs Instead of Floodways: Ever since the Adopted Plan became law in 1928, the Louisiana Board of State Engineers has urged in each published biennial report that the Adopted Plan be amended by including the construction on the tributaries of the Mississippi River of a sufficient number of reservoirs to eliminate the necessity for the use of the Boeuf floodway in taking care of future floods. In addition to the great value of eliminating the expensive Boeuf floodway, the reduction of flood peak flow by this method would reduce the area and amount of flooding in other floodways, and also would tend to reduce the area submerged by floods in backwater sections. Such reservoirs of course would also have the customary value for other purposes of any multiple-use reservoirs.

The Army Engineers have been studying since 1927, the question of flood control as affected by a system of reservoirs but have not yet issued their final report on the subject.

Undoubtedly some reservoirs will ultimately be built for other purposes. As such construction proceeds it will have a progressively increasing influence on Mississippi River floods and on floodways, reducing the frequency of their use, reducing the maximum flow through them, and thus reducing their needed depth and width.

As headwater reservoirs are progressively built, flood crests will be reduced in height, and the backwater areas will be correspondingly decreased in size. A lowering of the maximum flood crest by one foot will remove 225,000 acres from the backwater areas, and add them to the class of lands protected from all floods. The cost of the existing main levees along the Mississippi is about $300,000,000. Probably 12,000,000 acres at present are completely protected from all overflow. This gives an average cost for the main levees of $25 per acre of completely protected land. Using this figure as the value of protecting additional land in the overflow areas, we obtain nearly $5,500,000 as the value, for this purpose, of lowering maximum flood crests by one foot.

Fuse Plug Levees: When the river overtops a levee, the water rushing down the land side of the levee rapidly washes it away and destroys it, thus producing the dreaded crevasse. In addition to destroying the levee the falling water commonly washes a great hole in the ground which may be as much as 60 feet deep and extend back from the levee a quarter mile or more. The excavated material is spread over the surrounding fields to a depth of several feet, damaging the land for a considerable distance. When the levee is repaired, it is necessary to carry it either in a new and lengthened location around the "blue hole" or across it after filling it up. Either process is very expensive.

The fuse plug levees at the upper ends of the Boeuf and Atchafalaya floodways are some 30 miles long. The place where they are to be crevassed is left to chance. Likewise the width and depth of the crevasse is left without any human control. Because it is impracticable to repair a crevasse until the flood has subsided below the top of the river banks, the discharge into the floodway will continue over a much longer period than is necessary for flood control.

A consideration of the cost of repairing crevasses, as well as the other objections to fuse-plug spillways explained above, indicates that fuse plug levees should be replaced by concrete spillways, which would limit the flow into the floodways both in quantity and time, and would not require repair or rebuilding after every flood. The extra cost of concrete spillways may not be the controlling factor.

IV. Project Areas

The Yazoo Basin: Of the 6,600 square miles in the Delta parts of Yazoo Basin, nearly one-third is now subject to headwater flooding, notwithstanding the fact that the Mississippi overflows have been eliminated. The present hazardous situation of these lands prevents their full development for agricultural purposes. By reason of existing unsatisfactory conditions, clearing, drainage, and settlement have been only partly completed.

The cost of the existing Mississippi levees along the Yazoo Basin is about $75,000,000. Deducting the backwater area, 1,700 square miles, from the whole Yazoo alluvial basin of 6,600 square miles, leaves 4,900 square miles which has received some degree of benefit from the construction of the levees. The average cost is $24 per acre. But less than half of the alluvial basin is at present actually protected from all flooding. Using half, however, for the purpose of computation, or 3,300 square miles as the amount completely protected, gives an average value of $35 as the cost of the present Mississippi levee per acre of completely protected land.

A considerable portion of the unprotected area has been formed into independent drainage districts, which have attempted to obtain flood protection and drainage, but in many cases their efforts have been conspicuously unsuccessful. In some places where levees have been built on both sides of a stream by separate districts, in times of dangerous floods people residing on one side of the river have dynamited the levees on the other side in order to release the pent-up water and thus relieve the danger to their own property. This has led to a state approaching armed warfare, and serves to emphasize again the necessity for coordinated planning.

The lands still subject to headwater flooding are chiefly in a strip about 100 miles in length, lying along the eastern margin of the Yazoo alluvial basin. The flooding problem arises chiefly from the torrential run-off emptied into the area by a series of rivers draining the hill country still farther to the east. These rivers finally unite to form the Yazoo River. The chief streams, named in order beginning at the northern, or upper end of the basin, are the Coldwater, Little Tallahatchie, Yocona, Skuna, and Yalobusha Rivers.

This partially undeveloped strip lies adjacent to the most valuable and prosperous part of the Yazoo delta and is readily accessible both by highway and railroad. The reasons why this area has never been successfully exploited under state agencies using the methods customary in that region seem to be—

(*a*) The technical questions involved are unusually difficult and complicated.

(*b*) The affected area is so large that the customary procedure under the state drainage laws become more than ordinarily difficult.

(*c*) The areas affected bv the different rivers overlap in such a way as to present many conflicting interests, and thus it is rendered unusually difficult for the different communities to agree upon a plan of procedure.

(*d*) The magnitude of the unusual difficulties and the cost of overcoming them has reduced the prospective profits to the private land owners to such a point that it has been impossible to persuade all the landowners to join in the cooperative undertaking.

In the organization of drainage districts and the construction of drainage works in the past it has been customary to consider the matter a strictly engineering question, and the projects have thus been planned and constructed without much reference to the subsequent problems of clearing, reclamation, settlement, community organization, and finance. This old method has nearly broken down in the face of increasing difficulties and complexities. The time is ripe to initiate a new, more comprehensive and enlightened system of land reclamation and community planning designed to secure ultimately to the settlers an improved standard of living. This area seems to be an ideal location for such an attempt.

Although it is located in the heart of the cotton belt, authorities will agree that to secure the most stable and prosperous development there should be established a more diversified type of farming than hitherto used, including much more raising of livestock and the various kinds of fruit and garden truck.

The location is such that if properly planned in advance, the complete reclamation can be carried out progressively in a series of independent steps or units spread over as long a period as may be desired, say 20 years or more. If not completely and properly planned there will certainly be great losses in economy and efficiency, and possibly such errors in arrangement as will make impossible any ultimate complete development.

The data at hand indicate that for the ultimate complete development there will be needed the construction of 7 flood-control reservoirs with additional ditch and levee work. The cost of the complete engineering construction work will be about $50,000,000. To cover the clearing of the land and the improvements needed to make it ready for cropping will require perhaps an additional equal sum. Of course this total sum may be spread over as long a time in the future as may be desired. The proposed reservoirs might also have an appreciable flood control effect on the lower Mississippi.

The first step in this project should be the carrying out of the needed field investigations and the preparation of working plans. The investigations should include study of the soils throughout the area, determination of the best systems of cropping and farm management, and a thorough consideration of the best means for developing the highest and most desirable type of community and social life. The engineering studies should embrace the determination of the best arrangement of reservoirs and their capacities, the location and sizes of outlet drainage ditches, necessary floodways, and river channel improvements, and methods and progress schedules for land clearing and highway improvement.

Since the preliminary investigations and preparation of working plans will be so complicated and comprehensive, it seems most appropriate that the planning be considered a Federal task. It ought to be begun at the earliest practicable date so that the execution of the project can begin as soon as possible. The completed plan should not only cover all the engineering and economic features of the project, but should also provide for the administration of a land-settlement program including the qualification of settlers, financing the purchase of land from private or public agencies, financing the construction of dwellings and the purchase of equipment, and aid in developing an appropriate type of farming.

The committee recommends that this study and planning be begun at once.

The St. Francis Basin: In the eastern foothills of the Ozark Mountains in Missouri the St. Francis River rises, then enters the alluvial valley on its northern edge, and pursues a meandering course through the valley for 310 miles before joining the Mississippi near Helena, Arkansas. A part of the Delta area tributary to the St. Francis is in a highly developed state, but torrential floods in the river debouch from the foot hill region onto the valley floor and make difficult the protection and drainage of much of the land. Levees along the stream in various places have been overtopped and destroyed many times, rendering the efforts at land reclamation in these places almost futile. It is evident that control of floods in the upper course of the river by building one or more reservoirs in the foothill section will greatly simplify the problem of land reclamation throughout the Delta section. Obviously, utilization of the drainage area should be studied and planned as a whole and not in isolated parts as has been done in the past. Information already at hand indicates that if the whole river is treated as a unit, feasible and economical plans for its control and profitable development can be worked out. The problems are very similar to those in the Yazoo Basin.

It is recommended that the intensive study and planning of the St. Francis Basin be initiated at an early date.

The Black River Basin: The Black River rises in the Ozarks, enters the alluvial valley near Poplar Bluff, Missouri, and flows in a meandering course parallel to and just west of the St. Francis, for a length of 210 miles, until it joins the White River above Newport, Arkansas. Numerous detached areas within the alluvial area have been successfully reclaimed, but many others have had but indifferent success. The problems closely parallel those on the other streams subject to headwater flooding. A number of favorable appearing reservoir sites exist on the headwaters of the Black and its tributaries; and the use of reservoirs to assist in land reclamation in the alluvial section is plainly indicated.

The committee recommends the same unified study and planning for this basin that was discussed in detail for the others.

BOOK III TOWARD SOLUTION

SECTION II

AGENCIES

THE INTERRELATION OF INTERESTS

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THE INTERRELATION OF INTERESTS: LOCAL, STATE, REGIONAL, FEDERAL

Water has no respect for political boundary lines or for the dignity of States, as school children have learned since the day of King Canute. Yet flood, drought, and storm may sometimes be conquered, when the people are able to go into battle with adequate engineering plans and with organization suited to vigorous war on the forces of nature. The American people have established a partial control over their streams and other natural resources, and now in order to keep what they have won they are obliged to extend their control and to develop whatever public agencies they may require for that purpose.

With the growth of population, and with the demand for services that can be performed only by united endeavor, the functions of government have necessarily expanded. When a locality becomes too thickly populated for the continued use of individual wells, the local government is called upon to supply city water and city sewers. Public authorities are established not only to build schools and roads but also to provide for flood protection, irrigation, and drainage. Problems of development and of common protection arise that cut across existing boundaries, and new governmental agencies have to be created to serve as instruments for handling these regional needs. The control of water resources is peculiarly liable to require new district or regional organizations, because the local and State boundaries do not ordinarily coincide with drainage basins or climatic areas. Nature provides the problem in a geographical shape that requires a corresponding area of public action for its solution.

Value of Local Governments

In the initiation and management of public projects for control of water and other natural resources, the traditional function of local and State activity is of permanent value in a social order of the American type. Conditions change so rapidly that continuous and concurrent experimentation is a necessity. Moreover the advantages of local knowledge, and of local interest and responsibility for the success of a project, require the full utilization of local and state governmental machinery. On the other hand, there are many township and county governments, in various parts of the United States, that have ceased to fill any useful place in the public service. Even the new districts which are continually being created for special purposes may in certain cases become useless because of new developments and changing conditions. The public interest will be best served if while new governmental units are being formed, the old ones that are no longer useful should be liquidated. At the same time, when new duties that arise can be taken over by existing governments through agreements or compacts among themselves, the effect may be to vitalize the old governmental units as well as to avoid the need for new ones. The necessity of obtaining effective action, on the one hand, and the need for preserving the advantages of local initiative and responsibility, on the other, define the field within which the organization of public attack on water control and similar problems can be carried on.

Regional Organization

The technique of organizing for public work is already well developed. Our present institutions are being readily adapted or extended to carry the functions that arise. Where the physical problem to be attacked transcends existing political boundaries, several types of regional organization have been used. Of these the most informal is the conference, such as the New England Council or the Ohio River Interstate Council of Health Commissioners, having in its earlier stages no authority other than to make recommendations to the several states concerned. The Ohio River Board, for example, is reported to have cleared up many cases of stream pollution that might otherwise have led to litigation.

Next in order is the Authority or other form of publicly owned corporation, of which the Port Authority of New York is an example. The Authority has power to carry on various operations that cut across political boundaries; it can levy fees for the use of its facilities, but not taxes.

The intrastate Conservancy District is a type of the regional entity having definite boundaries and the power to tax, and created specifically for the performance of a definite public function such as education or water control.

Between the States, the Federal constitution permits the establishment of Compacts, or treaties with the approval of the Congress, whereby the relations between state functions in a region are defined, and suitable authorities are set up for the performance of the actions authorized in the treaty.

Regional Authorities may also be set up by the Federal Government for controlling rivers that cover a number of states. The Tennessee Valley Authority is of this type.

Initiation of Projects

The origin of projects for protection or development may be local or Federal. When a demand arises locally for action that cannot be carried out by any one local government, the Federal Government can be of assistance in providing information as to the physical factors of the problem. The Government at Washington should stand ready to make investigations of broad scope of interstate projects, when requested by the States, in order to supply complete and impartial factual data as a basis for State agreements.

In addition, as the Federal Administration may become aware of conditions that suggest the desirability of interstate action, it should be expected to investigate such conditions and to call attention to the opportunities for protection of development that may be disclosed.

As the organization of a project goes forward the planning of actual operations should be done by the various governmental authorities involved. (The relation of local, state, and national authorities to the general problem of planning is treated in the following discussion of planning.) In addition to the physical and operational plans, there shall be established a definite understanding among the governments concerned, as to those responsible for the various parts of the operation, and those who are to pay the costs.

Measurement of Benefits

Most projects having to do with water are of direct benefit to individual and business interests in a particular locality, and the tangible direct benefits may often be estimated with a fair degree of accuracy in terms of dollars and cents. Estimates of tangible benefit are useful not only as a basis for assessments but also as a guide for general planning. Tangible benefit is at least a definite visible measure of value, and in the absence of secondary factors of an unfavorable nature, it may well be used in establishing priority of one project over another of the same type. A secondary advantage of giving preference to projects showing tangible benefits lies in the fact that such projects are most likely to command popular approval.

On the other hand, the extent to which the nation as a whole is interested in a particular project cannot generally be measured with any accuracy; yet a national interest may exist in many different ways. Flood control, for example, while it may be primarily beneficial to the residents of the protected district, may also affect favorably the Federal tax revenue, the volume of interstate commerce, the security of military supplies, the burden of emergency relief, and many other responsibilities that in law or custom rest on the nation as a whole. On the other hand, local construction for flood prevention may increase the hazards of other localities, and may even aggravate rather than improve the general flood situation. Similar relations may appear in the case of reclamation projects. On the one hand, the national wealth may be increased by the produce of reclaimed lands, or on the other hand there may be in some cases a dislocation of markets that will occasion losses of national income. There are also cases, such as those involving stream pollution, where the tangible benefits accrue generally to people who cannot be assessed by the district in which the improvement ought to be made. There the Federal Government is interested in facilitating action for the national welfare, and may be called upon to assist in the adjustment of unequal burdens through subventions chargeable to the national budget.

Federal Responsibility

The Federal Government, as agent for the whole American nation, is in practice held responsible for the preservation of a tolerable level of national welfare. Whenever the people are irritated or injured by events that originate outside their own community or that arise from obscure causes, they are naturally inclined to blame the Federal Government. With the growth of the country the responsibilities thrust upon the central government tend to increase. The number of people who are settled where they are subject to floods, water pollution, or other physical damage originating beyond their own neighborhood is continually growing. In a similar sense, with the growth of interstate and interregional commerce, the several parts of the country are coming more and more to depend for their prosperity on the prosperity of their customers in every other part of the United States. When a locality finds its commercial income diminishing, the cause of its trouble may be remote and obscure, and no other agency than the national government appears to the citizen to be large enough to find and correct the difficulty. Moreover, in any free system where business planning is done by many different private interests, there appear spontaneous dislocations. Certain areas develop an unfavorable trade balance, which, if allowed to persist, leads to a stagnation of national trade in general. The relative distribution of income among individual citizens may take a form that fails to provide adequate markets for productive industry. In other cases technological developments may destroy certain industries, creating dislocations beyond the capacity of local resources to adjust. Maladjustments of these types can be reduced to tolerable dimensions only by a central government that has power to levy general taxes and to spend money at those points of the economic system which show signs of breakdown. With the growing size and complexity of the country, the citizen is faced with an increasing number of problems, both of physical and of economic adjustment, that are so widespread or so obscure and complicated in their nature, that he is led to look more and more to the central government to act as his agent in finding and applying a solution.

Under these circumstances, the demands upon Government—local, state, regional, and national—are continually shifting as new opportunities for beneficial action appear, or as new dangers from pests, from flood and storm, or from economic dislocation, call for measures of common defense. The necessity for a high degree of flexibility in the functions and relationships of the various levels of Government is enforced by the demand of the people that by one means or another acceptable conditions must be maintained. There are, therefore, definite limitations to the usefulness of the positive criteria of tangible benefit, as guides for the determination of relative responsibility in promoting and financing public measures of development or defense. For one thing, a project showing a high tangible benefit to one area may involve serious damage elsewhere. The criterion of tangible benefit should not be held so that it will force any action the results of which on the whole will not be beneficial. Certain drainage projects have not met this test. If projects are without exception excluded unless they show some stated margin of tangible benefit, the total activity may be so restricted as to vitiate the purpose of a national program. Although, as is evident in the earlier part of this report, the principle of local contribution in accordance with tangible benefits should be emphasized, it nevertheless is clear that, if preplanned public works in times of depression are *unduly* restricted by the financial incapacity of the local beneficiaries to bear their normal share of the expense, the continuing loss of national income may become an urgent consideration.

In view of the complex network of intangible benefits connected with most public improvements, a precise allocation of responsibility and costs is not in all cases ascertainable. The immediate tangible benefits, therefore, while they are indispensable as an instrument of planning and administration, should not be allowed to create an insuperable obstacle to action. The ideal allotment of costs would be that which would produce the best total economic effect within the limits of public support and of administrative practicality, with due regard for all equitable considerations.

Public Approval

The administration of public improvements, in order to be successful, must be so arranged as to win and retain the approval of the public. The people are the "owners", and without their consent no program can be long maintained. As owners the people can require the government to do, or to attempt, anything that they want done. The government has, therefore, the practical duty of estimating correctly what will be best for the public welfare in the long run, and of bringing all the relevant facts to the attention of the people. The relation between spontaneous local activity and Federal guidance needs to be adjusted constantly to the necessity of retaining popular support on the one hand and on the other of obtaining as favorable a result as possible in the long view.

The national interest in local improvements need not always require the prosecution of every particular project in a given class of work. The nation is interested in the total amount of public health, soil conservation, or flood control, rather than in obtaining one hundred percent of nominal collaboration with a rigid plan. Where a particular locality is unprepared to go along with the general program, it may often be left out without serious injury to the country at large, provided the general rate of national progress is favorable. In such cases the effect of time, example, and discomfort, is often the most practical and effective way to ultimate collaboration.

The difference between what is necessary and what is desirable should be kept clear in the public mind as general plans of administration are formed. When sudden disaster threatens death to human beings or the destruction of basic resources such as the soil, the people are faced with inexorable forces that must be met. Then all grades of Government must use every available means to arouse the people and to organize for immediate action against the common danger, and large assumptions of centralized power are quickly validated by popular approval. When, however, quick action is not imperative, or when the proposed action is a benefit rather than a defence against danger, the approach should be through education of the popular will until sentiment is built up to the point where action can be taken. The relative degrees of immediate Federal responsibility and of justifiable reliance on local initiative are thus affected by the seriousness and immediacy of the need for large-scale and united action.

Federal leadership in fields where emergency is not apparent may be exercised in several ways: by conference, dessemination of technical information, by making surveys and pointing out the requirements of balanced national development, by acting as referee and adviser for parties who wish to reach a working agreement, and by using grants-in-aid to provide or encourage the construction of model examples. By such means the public may be led to appreciate various necessary or desirable types of action that will later become either local, regional, or Federal functions.

Limitations of Planning

In seeking popular approval for any program Government should obviously avoid the assumption of undertakings which in the nature of things result eventually in waste and ineffectiveness. There are, for example, in any system painful but necessary happenings such as the death or failure of once hopeful organizations. Regions and cities, as well as industries, grow and then sometimes decay and become no longer able to support a population. Free initiative, with all its manifest advantages, involves by necessity the freedom to fail and to disappear from the scene. The inhabitants of a declining region may look to the Federal Government to restore to them a prosperity that has in hard fact been killed by changes for which there is no remedy. In the researches of any central planning board there will appear occasional painful facts such as these. Yet, if elaborate public works are thrown into a dying area as a means of relief, they will soon stand as a monument of folly and extravagance, and the power of government to carry on work where it is really useful may be placed in jeopardy.

In the face of painful changes for which there is no known remedy, government, if it is to retain the confidence of the people, will need to protect itself by limiting the extent and definiteness of its plans, so as to leave room for contingencies. By no means should it take responsibility for protecting all local values, for preserving all local institutions once established, or for preventing the bankruptcy of all private or public enterprises. The law of nature requires that free initiative have a reasonably free death rate, and a Government that permits free enterprise with one hand and guarantees universal success with the other, will soon be replaced.

In order to establish a useful degree of Federal planning and leadership without loading the central government with undue responsibility for inexorable fate, several factors are needed. Policies leading to decentralization of industry and local self-sufficiency are vital, as means of providing a cushion of free activity and economic opportunity for the details of which the Federal Government need not be responsible. Policies for establishing and maintaining a high state of business activity and a well-distributed national income, vital for general reasons, are desirable in this connection as means of reducing the impact of local failures. Those who suffer can then more easily find new sources of income, and thus relieve the pressure for Federal intervention. Above all, the Federal Government, in its recommendations and plans, will need to make clear to the people that its function is not to take over the direction and responsibility for individual enterprises, but to provide those physical and economic adjustments that will lead to a generally favorable environment in which local enterprises may operate.

Summary

The increasing complexity of the national life lays upon governments, local, State, and Federal, a growing and constantly shifting burden of new duties, in the way of providing opportunities for utilization of water and other resources, and of protecting the people against natural or economic disasters. Local governments, existing or created ad hoc, are called upon to initiate projects that will produce tangible local benefits; at the same time the nation as a whole has many direct and indirect interests in the coordination and successful prosecution of public works. The Federal Government is bound to participate in stimulating, aiding, or controlling public works, in proportion to the direct or indirect effect of the proposed work on general national interests, in proportion to the stress of any existing emergency, and in proportion to the necessity of utilizing Federal expenditure as an alterative

The Interrelation of Interests: Local, State, Regional, Federal

and tonic for the general economic system. The practical allocation of local and Federal responsibility is a matter of relative benefits, technical analysis, practical administration, and public opinion combined. The methods of organization must be so planned that the advantages of local knowledge and responsibility may be retained, that the national interest may be served, and at the same time that continuous popular support may be available. The duty of the central government is bounded on one side by the necessity for creating a national situation that will satisfy the citizenry, and on the other by the necessity of avoiding too great a load of responsibility for local failures and unavoidable accidents.

In general, within the limits of law and of public opinion, the responsibility of the Federal Government is to promote and balance by every available means all actions that will increase the total national income, the facilities for providing public services, and the physical and economic security of the people.

PLANNING

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I. On the Nature of Planning

If it should be decided to "put to work", as the phrase goes in industry, some comprehensive program of better utilization and control of water resources, it becomes of interest to know something of the kind of planning that would be involved in carrying through such a far-flung social undertaking.

1. *Generic Meaning of the Term:* In its common sense "planning" is as old as man. Peasant, husbandman, merchant, industrialist, ruler, have always made plans. Such planning, however, pivots on the individual and carries the limitations of his particular interests, abilities, and facilities, varies as these change, and terminates when his interest ceases.

2. *Technical Meaning of the Term:* Used by those who advocate planning of public affairs the term has come to have the technical meaning given to it by engineering and industry. Engineers in large-scale construction operations and managers of large-scale business enterprises have learned that the condition of success is a precise, coordinated, economical management of operations, and that this condition can be met only by the creation of an institutional mind which has its power of perception (investigation, research), of memory (records), of reasoning (analysis), and of design (planning). Such an institutional mind is a composite of, and yet is distinct from, the minds of the individuals of which it is composed, who, as individuals, may come and go; has a continuing life coincident with the life of the enterprise; and can think and arrange affairs with that large perspective made possible only by such characteristics. When a Goethals has assumed responsibility for the construction of a Panama Canal, or a Rockefeller has undertaken the creation of an industrial enterprise, he has invariably set about the development of such an institutional mind as the only reasonable assurance of consistency of component operations and the success of the undertaking.

This capacity to think in terms of experience larger than that which comes to any individual, to define distant goals, to arrange highly efficient ways and means of attaining them, and to pursue these distant ends consistently, yet with a flexibility which permits adjustment to changing conditions, is the dominant characteristic of institutional planning.

3. *Planning and Control:* The attainment of a complicated objective requires, first, the design of an arrangement of ways and means by this institutional mind; second, an actual manipulation of the ways and means—usually by another than the planning agency—in accordance with the predetermined arrangements. Therefore responsibility, authority, and control are inherent in planning. Yet these can be—have been in certain instances—provided for in a manner and with a quality which is valued in a political democracy.

To make responsibility, authority, and control both democratic and effective the planning and the execution must be in accordance with "laws of the situation," the situation including both the objective and its environment. The planner must know as much as science makes possible about all natural and human forces involved in the achievement of the objective, must evaluate their degrees of flexibility and must arrange for either manipulation or conformity in accordance with their natures. This is an inexorable condition of planning, whether individual or institutional. Water cannot be made to flow uphill and ships cannot be made to sail up shallow rapids, but, by an arrangement of materials which takes the form of locks, navigation uphill may be made possible. Navigation may be thus provided, but shippers cannot be compelled to make use of it if it is not to their interest so to do. Therefore in planning, the design must be such that, in execution, the control and authority reflect—now obey and now manipulate—the forces inherent in the situation, and are not the expression of arbitrary desires and unintelligent assumptions.

Planning offers itself as the salvation of essential democracy. As a democratic society develops a more complicated social-economic life, it becomes less capable of surviving uncertainty and drift; of surviving as democracy without continuing purpose, control, and authority. It must therefore develop its institutional planning. Recognition of inflexibilities as well as flexibilities in situations is of especial importance to planning in a democratic society. Over a period flexible and inflexible factors may undergo change with respect to these characteristics, but in making plans at any particular time they must be recognized as they then are. A democracy must make its planning the expression of a genuinely collective interest, purpose, and will; must have regard for inflexible human as well as inflexible physical factors; and must confine its manipulations to the plastic factors inherent in the situations being planned. In this way individual and group relations in adjustment to environment may be organized and brought under control and yet remain democratic.

II. Organization for Planning

1. *Planes of Planning:* Because of the complicated organization and operations of multiple-plant enterprises, these offer the most valuable suggestions for social planning; in fact, theirs is the only pertinent experience on which we may draw. In their experience it has been discovered that the planning least subject to confusion and self-defeat and most effective in coordination is organized on three planes:

a. Directive Planning is concerned with the general direction of a far-flung enterprise, calculates in terms of plants as units, formulates plant programs, schedules, and budgets as directive instruments, and leaves to each plant the more detailed planning in terms of its units. These plant schedules and budgets are the standards by which plant operations are coordinated and their efficiency judged. The comparison of periodic plant-progress reports with these schedules and budgets effects directive control. Control through specifications of major purposes, ways, and means—environmental control—is the characteristic of this plane of planning.

b. General Administrative Planning is the planning by the general management of the individual plant. In conformity with directive specifications it calculates in terms of major departments as units, and formulates programs, schedules, and budgets as controls for these departments. It leaves to the departments more detailed planning for their operating units. General administrative control is effected through comparison of departmental-progress reports with the general administrative schedules and budgets. Here again environmental control is more characteristic than specification in detail.

c. Operative Planning is the responsibility of a departmental management. It calculates in terms of orders received, and of the processes and machines of the department. Within the major controls established by directive planning and the secondary controls established by general administrative planning, it designs the related functional activities of detailed operations. Here specification in detail enters.

With respect to specification in detail—by some called regimentation—two characteristics should be noted:

(*a*) The farther the plane of planning from the plane of actual operations the less detailed is the planning and the larger the units in terms of which plans are made. Detailed planning can be done only by those who are at the scene of operations and know intimately the unit acts to be performed and the processes, machines, and skills involved.

(*b*) Detail in specification is a function of the technological methods necessary for achievement of the objective, not a function of planning itself. Planning does not seek detail in arrangement for its own sake. It seeks rather to discover the least prearranging which the technology of achievement of the particular objective requires.

2. *Steps in Planning:* In directive, general administrative, and operative planning, considered individually or as an integrated whole, there are five inherent major steps:

a. Definition of Purpose: The designing of ways and means for achievement of an objective cannot be begun until the objective is accurately defined. The desired end governs every step of planning. Many failures in planning may be attributed to disregard for this condition precedent. It is a folk saying that a problem well stated is half solved. A precise and complete definition of objective is a long step toward planning for its achievement.

b. Formulation of Policies: Not only does decision to achieve an objective reflect a major policy, but achievement is governed by collateral policies. An entrepeneur may for instance decide to construct and operate a textile mill. The necessary planning will be conditioned by such policies as those respecting the market to be served, the variety of items to be fabricated, and the apportionment of capital between physical equipment and working funds.

c. Formulation of Program: To bring ways and means under organized consideration and evaluation there must be a working formulation of their possible arrangement in the form of a tentative program of action. This program is to planning what an hypothesis is to scientific research—a guide to orderly procedure in discovery, evaluation and application of data.

d. Design of Plan: Revision followed by still more revision of the tentative program, as data are acquired and evaluated, results in a refined final form of the program in which ways and means of accomplishing the objective are brought into precise qualitative, quantitative, and functional relationships. This constitutes the plan.

e. Differentiation of Projects: A plan is usually composed of groups of operations, each group having an integrity which permits it to be carried through as a thing in itself. Such an integral group of operations may be identified as a project. For instance, in building construction the foundation work, the erection of superstructure, or the installation of a lighting or heating system, is each a distinct project. Each can be carried out as a separate sub-objective because coordination has been effected by the general plan of which each is a part.

Any one of such related projects, if it be large and complicated enough to call for such a division—for instance, the projects involved in the construction of a Panama Canal—may have its particular planes of directive, general administrative, and operative planning.

3. *Processes of Planning:* Three major processes are characteristic of planning, whether it be directive, general administrative, or operative.

a. Research and Investigation accumulate the data by which the ways and means of achievement that are to enter the final design may be evaluated. Such research and investigation eliminate guess, hunch, and prejudice, discover the degree of flexibility and inflexibility of factors, and increase the probability of the success of the resultant plan. Research and investigation are of two kinds: the continuous research and investigation which are constantly engaged in accumulating basic data for general subsequent use; and the research and investigation which focus on problems of a particular objective.

b. Standardization translates scientific information into terms pertaining to materials and apparatus to be used and to ways of doing things familiar to those concerned with execution. The specification of a particular type of machine on which to fabricate a particular product, or of a specified grade of materials for a particular piece of construction, is a standard. It is in terms of such basic standards that a detailed operative plan is composed. Such standards are never considered final and are subject to continuous rational revision.

c. Design is the final element of the planning process in which ways and means of achieving the purpose, based on research-determined standards, are formulated into a logical and effective scheme of coordinated, synchronized acts utilizing specified facilities.

Although these elements of the planning process are common to all planes of planning, each uses its appropriate types of research, standards, and design. As has been observed, the farther the plane of planning is from the plane of action and from the planning of constituent projects, the less detailed the specifications. However, the standards and resultant specifications of all planes of planning must be consistent, as they may be if based on the same fundamental researches and checked one against another.

Planning, in this technical meaning of the term as understood by large-scale engineering and industry, has not yet been adapted to the social purposes of government in the United States. In the common meaning of the term, individual leaders and individual administrations have had their individual plans, but these have pivoted on individuals and have been transitory. A continuing institutional mind, especially charged with the responsibility of formulating some comprehensive long-run social plan, has never been established. However, the complications and confusions of our cultural and economic life are becoming such that the planning of a better adjustment of national life to natural environment appears essential. The technique of such planning cannot make a better beginning than to adapt the technique developed by engineering and industry.

III. Directive Planning of the Utilization and Control of Water Resources

1. *Federal Responsibility:* Comprehensive regional planning of the utilization of water resources is unquestionably a responsibility of the Federal Government. Federal responsibility rests on these among other facts: (a) the problems transcend state areas and the physical factors cut across state lines; (b) the Federal Government has for years been particularly concerned with navigation and more recently with flood control; (c) water problems have in other respects become increasingly a problem of the Federal Government; (d) it has numerous agencies already experienced in the particular kinds of research and investigation involved, and in formulating appropriate basic standards; (e) national relations and influences play a progressively larger part in cultural and economic life; and (f) many believe the Federal Government should discharge the moral obligation of rectifying the results of unwise early Federal land policies (involving water factors) which have permitted in some cases the misguided efforts of individual settlers, with the

ultimate consequence of jeopardy to their present welfare and security.

2. *The Evolutionary Point of View:* The application to public affairs of the principles and technique of planning offered by the rich experience of engineering and industry must first of all be conditioned upon the social nature of the proposed planning.

In regional planning the objective must be defined in terms of the desires of an existing society; the standards must take into account its traditions, habits, and prejudices; the planning and executing instruments employed must be, insofar as is technically desirable, existing institutions. One of the first problems of regional planning research is to inform itself with respect to such matters and to ascertain how harmony may be brought between existing institutions, mental attitudes, and habits on the one hand, and the developed technique of planning on the other hand. Beginning in this manner social experience in planning will influence traditions, habits, prejudices, desires, and institutions, and also the planning technique itself; and by circular reactions will bring progressively more perfect harmony between principles, technique, and conditions.

3. *Utilizing Available Institutions:* Organizations are constitutionally and legally available to serve as agencies of regional planning and of the execution of plans. These are agencies which may easily be expanded or created by Federal, state and local governments, respectively. From among these should not be omitted interstate and interlocal-government "authorities" which may be created under statutes authorizing compacts. Provided there is a will to plan and a willingness to come into cooperative relations, a great variety of institutions is available for the purpose.

4. *General Resources Planning:* Although here concerned chiefly with directive planning of the control and use of water resources, we should not fail to perceive that water is but one of several related classes of resources and that promotion of the public welfare by wiser use of one particular resource cannot effectively be accomplished without its being incorporated into a master plan of utilization of all resources. Therefore, from the point of view of an agency concerned with directive planning of the use of water resources, its planning should be conditioned by a comprehensive plan for the coordinated control and utilization of all resources. It should begin its planning subject to environmental controls thus established.

5. *Organization for Regional Planning:* In private industry it has come to be realized that the once common assumption that "my business is entirely different from yours" is true only in respect to such matters as materials, technology, and markets, and that all businesses are essentially alike in respect to fundamentals of management, among them planning. The framework of planes, steps and processes of planning, which have been described, is common to all. The differences between a public and a private business do not affect fundamentals of organization for achievement of objectives, provided there is the will to achieve them precisely and economically. Therefore, one may accept the framework of planning developed by private industry as adaptable to public purposes.

Consideration of available public institutions, to which reference has been made, suggests an orderly and logical allocation of planes of planning responsibility among them. Federal agencies would be concerned primarily with directive planning and think in terms of regional objectives and constituent projects. State and interstate agencies would be concerned primarily with general administrative planning of constituent projects; and lesser agencies, public and private, generally with operative planning and execution. This suggestion will be developed more fully below. Likewise the planning would involve steps and processes similar to those characteristic of planning in private industry.

6. *Definition of Objective:* For reasons which have been indicated the Federal directive planning agency would be best equipped to define the purpose and scope of any particular regional undertaking for control and utilization of water resources. It would of course consult with state and interstate agencies in working out the statement of scope and purpose, but on it should rest initiative and ultimate responsibility because its perspective, free from the particularism of more restricted points of view, is the only perspective adequate for such responsibility.

7. *Research:* It also would be the agency best equipped through association with specialized agencies of the Federal and state governments to organize coordinated researches (conducted by both Federal and local agencies) essential to an adequate knowledge of the waters involved, and their behavior and relations. In this connection attention should be called to the urgent necessity that it should promptly organize the procurement of con-

tinuous records of the behavior of water, and accompanying researches, with a scope which has never yet been undertaken. This would involve that at all strategic points in a region provision be made for the accumulation and analysis of continuous records of rainfall, run-off, infiltration, water tables, subsurface deposits, stream flow, low water, floods and erosion; and the relations of swamps, reservoirs, lakes and rivers to other physical and cultural factors. While planning begun tomorrow would have to be content with such meager records of this kind as are now available, the concept of the planning agency as a perpetual institutional mind should inspire it to provide promptly for adquate continuing records and analyses for use twenty-five, fifty, and a hundred years hence. Paralleling such studies of a more strictly hydraulic nature should be studies of the social utilization of water for navigation, power, irrigation, sanitation, recreation, and so on; all designed to afford a more substantial foundation for future planning of the use and control of water in a program of better adjustment of man's life to his environment.

8. *Data and Standards:* Accompanying and consequent on these researches such a Federal directive planning agency should be continuously engaged in the consolidation of basic data and the formulation of basic standards pertaining to materials and methods used in the control and utilization of water, of the nature indicated in an earlier section, and should have them available for use in connection with the succession of programs and projects with which it would come to be concerned. As in industry and engineering, such standards should never be considered final; but at any time the latest revisions should be immediately available for each planning problem that presents itself.

9. *Education:* This Federal agency of directive planning should assume the responsibility of a continuous program of general public education respecting better utilization of water resources and better control of the destructive conduct of water, especially where, as in the case of erosion, its first destructive forms are insidious, do not attract local attention, and the destructive characteristics are seen only in large perspective. For illustration, it might undoubtedly be well worth while to inspire the enlistment of the rural school children of the country—rural Boy Scouts and Girl Scouts—under the guidance of educational and agricultural authorities, in a campaign to combat erosion in its initial, insidious forms of sheet and finger erosion. Similar maneuvers have been organized and carried through in suburban communities with respect to pests like the tent caterpillar. This suggestion indicates how planning may be made a means of enabling all citizens of a democracy to join the ranks of those seeking to thwart destructive and to release beneficial energies.

10. *Specific Programs and Projects:* In the face of concrete situations calling for better utilization and control of water resources, and with the data and standards being continuously acquired against such times of need, this Federal directive planning agency would be in a position to exercise the more definite planning function. In respect to this, its function would be: to design the over-all regional layout of a program, including any special investigations necessary to the development of a first hypothetical design into a final refined design; to indicate the nature of and relations of constituent projects; to indicate the general character of the layout of each particular project; to indicate the organization of states, localities and authorities for further planning and the execution of plans; to formulate the schedules of action and the budget of costs and their allocations; and not least, by interchange of ideas concerning objective, plans, methods and division of labor, to effect the arrangements whereby the several cooperating agencies would be brought into legal and technical relations for consummation of the plans. All this accomplished, the several parts of the over-all plan would be passed along to the various cooperating general administrative and operative agencies.

11. *Directive Contacts and Controls:* To assure coordination in carrying through the program of any regional development, even though general administrative and operative responsibilities would be passed along to other agencies, this Federal directive planning agency would possess facilities for observing and appraising the progress on all parts of the program, because detailed operative and general administrative plans would be components of and dovetail into the directive comprehensive plan. It would be in a position to assure the enforcement of all specifications, or correction of deviations therefrom, because of the authority accompanying Federal contributions to projects which are elements of a regional plan.

12. *Exclusively Federal Projects:* Undoubtedly in respect to some parts of an over-all plan or even in respect to an occasional over-all plan

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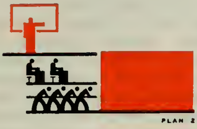

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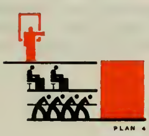

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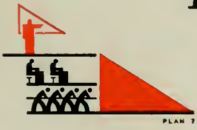
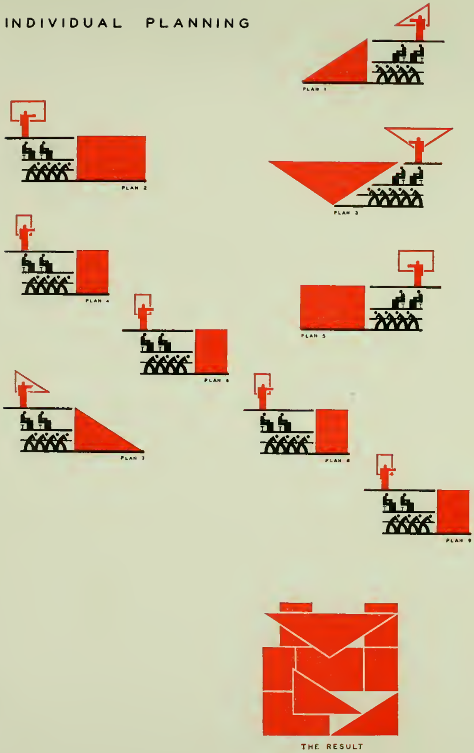
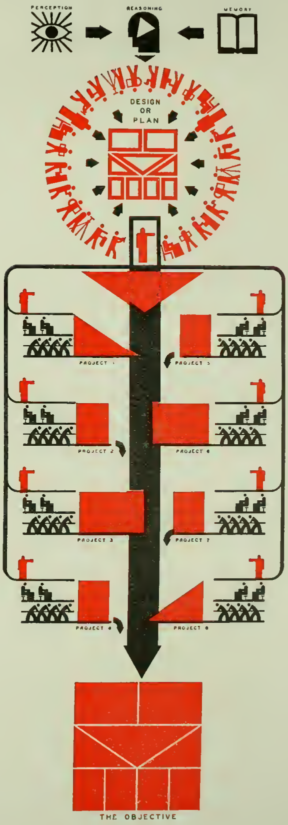


PLAN 7

INDIVIDUAL PLANNING



COORDINATE PLANNING



in its entirety, it would be found expedient for this Federal directive planning agency to assume the additional functions of general administrative planning, operative planning and execution—as is now the fact respecting major navigation projects. In such a case it should extend its organization to enable it to perform the additional functions. The extension of its organization would be by addition of a unit for the particular general administrative and operative planning, while the execution would usually be left by contract to some private agency or to the Corps of Engineers.

12. *Practicality of Planning:* Because government in the United States has not yet instituted planning with the comprehensive technique which has been here explained, discussion of what might be undertaken cannot avoid a theoretical flavor. However, it should be borne in mind that the technique has been validated by industrial experience and is one of the most practical and vital instruments of private business. Although first developed for control of fabricating operations, it has been applied progressively to merchandising, the general administration of plants, and directive administration of far-flung multiple-plant enterprises. It permits management of large-scale operations with an efficiency seldom realized in the small enterprises of half a century ago. Without it modern large-scale enterprises would be unmanageable, because the larger the scale of operations the more dependent an enterprise on planning. For this reason social enterprise appears to be even more dependent than private enterprise on such a technique of planning.

SECTION III

THE MISSISSIPPI VALLEY OF THE FUTURE

THE MISSISSIPPI VALLEY OF THE FUTURE

A map of what is now the United States, published about a century ago, reveals a good knowledge of the country as far West as the Mississippi River, some acquaintance with the Spanish Southwest, to which American traders from points on the Missouri River were already making regular trips, and a fair idea of the Missouri-Columbia route to the Pacific Northwest. But the details of the vast interior basin were not filled in. It was still believed, for example, that the Great Salt Lake had an outlet to the Pacific, perhaps at the Bay of San Francisco.

When we try to project our map of the Mississippi Valley into the future we encounter difficulties similar to those of the map-makers of 1834. There are no returned travelers to tell the story of shining mountains, inland seas, and rivers slipping out of the unknown. We must be guided by sights taken from familiar peaks and by dim landfalls on strange coasts.

Yet from the borders of the *Terra Incognita,* which we must leave to our children to explore, we can draw some intersecting lines, fix some latitudes and longitudes, and perhaps mark the beginnings of trails which will later become main-traveled roads. The analogy still holds if we consider the course and nature of these trails. The physical qualities of the country, its rivers and mountain passes, will have a part in determining their windings, but the needs, desires, and ingenuities of those who are to follow them will fix their destinations and their character.

Similarly, in attempting to chart the Mississippi Valley of the future, we must take account of physical factors which on the whole will not change; of human desires which likewise remain much the same from generation to generation; and of the degree to which humanity can adapt nature to its own ends. It is this latter element which is the most speculative.

If certain present-day trends were to be projected unaltered into the future the map would be a sorry one. We would be compelled to show increasingly large stretches of once fertile lands stripped of their life-giving humus, rivers breaking forth in floods of increasing severity as the denuded slopes permitted an ever-swifter run-off, industry and agriculture becoming ever more precarious, the life of the people on the land becoming more and more disorganized, and a steady increase of farm tenancy and of economic dependency.

Under such conditions local self-government would be likely to break down, and under the spell of a dire and never-ending emergency, economic and political centralization would steadily increase. The comparison of such a situation with the final days of the Roman Empire is not too far-fetched. Civilizations of the past have more than once decayed because of similar causes.

The values we most cherish in American life, in the geographical and perhaps the cultural heart of the American democracy, depend on arresting these tendencies. In many places the present report has suggested an extension of the Federal Government's activities and responsibilities. Actually, as the Committee firmly believes, such an extension, on the bases proposed, is necessary, not merely to maintain the prosperity of the Valley but to combat influences which would otherwise break down the spirit of local self-reliance and local self-government.

Life in the Mississippi Valley of the future need not be poverty-stricken or precarious. The forces making for health and well-being, once they are controlled, are greater than those which make for disaster. The quality of life in the Valley can be enormously improved. It need not go the way of the valley of the Nile, the valleys of the Tigris and Euphrates, where sands have drifted into old irrigation ditches and the sites of opulent gardens, or the stripped valleys of China. We have knowledge that the older civilizations lacked. If we synthesize that knowledge to make our plans, if we put a common purpose above local jealousies and conflicts of interest, the future is in our own hands.

A benevolent despot could bring about all the physical changes that are proposed in this report, but he could not make them permanent. A democracy, surrendering minor privileges here and there in order to save its essential liberties, can build just as solidly and more lastingly. Our democracy already has the necessary technique. It needs only a wider vision, a more realistic imagination.

The future cannot undo all the blunders of the past. It cannot, in any length of time easy to conceive, restore completely eroded lands to their primitive condition. But there are things we can certainly draw into our map of the future if we wish.

Such a map might show the disastrous kind of erosion finally checked. Instead of gullied hillsides and slopes from which the rich humus colors were slowly fading, it would show terraces; alternations of tilled land and grasslands; new forests springing up in belts and patches, tended as carefully as so many orchards. It would show, perhaps in variegated colors in order to make the contrasts more evident, the scientific uses of all the land in the Valley, determined after long studies of soils and climatic conditions. No farmer would be trying to grow corn on land fit only for timber, or wheat on land best fitted for grazing, or anything at all on land best fitted for recreation and the preservation of wildlife.

The rivers might not be entirely under control in times of major floods, but the crest of the floods would have been lowered by means of forest planting, sod cultivation, the building of multiple-purpose dams, and the creation of numerous minor reservoirs. When the rivers could not be held within their channels their waters would be allowed to flow into previously selected floodways, where the least possible harm would result. Low-water control would have advanced to a point where each community would be ensured of its necessities. Power lines would have flung an intricate, interconnected network over the whole region, with power "islands" in remote areas into which the major transmission lines could not economically penetrate. Every farmer's family would find its work lightened by the use of electricity. New manufactures, perhaps new inventions, might have restored some of their lost traffic to the rivers. Possibly recreational uses would have supplanted commerce on most of them. Playgrounds of all sorts, from city parks to wilderness areas into which no wheeled vehicle would be allowed to go, would be more extensive and more thickly spotted over the map. No reason would appear why they should not be. The intensive cultivation of only the best land would have restored to the Valley some of its original freedom and spaciousness. Population would have increased but crowding would have decreased.

The economic life of the region, being better organized, would be carried forward on a higher level. "Area projects" on the Lower Mississippi, in the Tennessee Valley and elsewhere, would have demonstrated the interlocking character of all human activities that are dependent on water. Means would have been found to halt the trend toward farm tenancy. The "sturdy individualism" of pioneer days would have been restored by the cooperation of national and local agencies, some governmental, some private, but it would be a cooperative, not a combative individualism. Little distinction would be made between the various forms of cooperation. The agency employed would be that which after a scientific survey of conditions seemed best adapted to the purpose.

Such a picture as this is not fanciful, even though we cannot certainly predict that it will be fully realized. It indicates what can be accomplished, in an American way, in a democratic society, through democratic governing agencies. It does not demand a break with the nation's traditions, but an application of them in new ways to new conditions. The nation can create such a Mississippi Valley as has been outlined if it collectively so wills.

POSTSCRIPT

INCLUDING CREDITS

This report of the Mississippi Valley Committee is in answer to our instructions to make a plan for the use and control of water within the Mississippi drainage basin, a vast area comprising all or parts of 31 states. An earnest effort has been made to show the relation of the great wealth of water resources in the Basin to the pressing problem of bettering the condition of its people and indirectly that of the whole nation.

While this answer does not embody all the divergent views presented, it represents the opinion of the committee as a whole; and it is submitted, not merely as one of many answers that might be made to our instructions, but as the one considered to be the best. While the control and use of water is the core of our assignment, the boundary between water and land problems is indefinite and shifting. In fact, any consideration of water problems leads inevitably to the life of the people who occupy the land.

The advantage of this type of assignment lies in the opportunity afforded to approach the problem simultaneously from many angles, to appraise all of the factors involved in their relative importance to one another and to the whole, and setting aside for the moment those of less immediate import, to bring those that remain to a common focus. In our effort to evaluate and choose from so much that is pertinent we have come to a clearer understanding both of the importance and difficulties of regional planning.

Impressed with the limited time and overwhelming burdens of those who are guiding the nation in these critical days we have accepted the responsibility of selection and condensation of the available material from the standpoints of significance, quick assimilation by the reader, and usefulness, both in the attack on pressing problems and in the formulation of long-time policies. Supplementary material, usually found in appendices to such reports, is on file in our offices.

In a very real sense the making of this report has been a cooperative undertaking. From those who have spoken at the large number of hearings held especially in connection with projects proposed for federal aid, from members of the Congress, and from such groups as that representing the railroads of the country we have gained both specific information and general perspective. From the various branches of the Federal Government we have received unreserved help and cordial cooperation. A number of universities and colleges in the Valley have rendered material assistance.

In the preliminary inquiries leading to the drafting of sections of the report, and in some cases in the drafting itself, we have had assistance from professional engineers not in the federal service. Acknowledgments are also due to special committees appointed to consider improvements on the Arkansas and Red River systems. To all these; to our technical staff, which brought to the novel task a high degree of competence, rare devotion, and an enthusiasm appropriate to the emergency; to the office staff, who have worked long hours and often under trying conditions; and to many others we express both appreciation and gratitude.

We recall with pleasure the service as a member of the Committee in its early days of Major General Lytle Brown then Chief of Engineers.

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